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ENGINEERING

An Illustrated Weekly Journal.

EDITED BY WILLIAM H. MAW AND B. ALFRED RAWORTH.

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(a) Brooms and brushes; (b) electric light sundries; (c) files; (d) fire bricks, clay and lime; (e) insulated wire; (f) metals; (g) oilman's goods; (h) cable jointing materials; (i) screws; (j) tools; (k) joint boxes and connections.

Forms of tender and further particulars can be obtained on application to Mr. G. G. BELL, Borough Electrical Engineer, 85, Fulham Palace Road, W., upon receipt of a stamped addressed foolscap envelope. Sealed tenders, endorsed "Tenders for Electricity Stores," must be delivered to me at the Town Hall, Hammersmith, not later than 4 p.m. on Wednesday, 12th March, 1919. The Council does not bind itself to accept the lowest or any tender.

LESLIE GORDON,
Town Clerk.

Town Hall, Hammersmith, W.
14th February, 1919. S 971

THE GREAT INDIAN PENINSULAR RAILWAY COMPANY.

The Directors are prepared to receive

Tenders for the Supply of the

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The Directors do not bind themselves to accept the lowest or any Tender.

Company's Office, R. H. WALPOLE,
48, Copthall Avenue, E.C. Secretary.
London, 26th February, 1919. T 102

IN LIQUIDATION.

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ELLIS OWEN,
Deputy Official Receiver and Liquidator.
117, St. Mary Street,
Cardiff. S 984

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Sealed Tenders, in the official envelope provided, are to be delivered to the undersigned not later than Nine a.m., 6th March, 1919.

The lowest or any Tender will not necessarily be accepted, and the Committee reserve to themselves the right to divide the work.

Tenders will only be accepted from firms who conform to the conditions of the Contract as regards paying the local standard rate of wages, &c.

W. J. BOARD,
Town Clerk.

Guildhall,
Nottingham.
26th February, 1919. T 84

APPOINTMENTS OPEN.

ELECTRICAL DEVELOPMENT ASSOCIATION.

The Committee of the above Invite

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Canvassing Members of the Committee will disqualify applicants.

G. T. EDWARDS, A.M.I.C.E.,
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Water Works Office,
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Secretary for Education.

Guildhall, Bristol.
25th February, 1919. T 64

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TERMS.—A three or five years' agreement in the first instance, free passage out and home again on satisfactory termination of service.

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All Candidates MUST have served a regular pupilage, or apprentice ship (where usual) with a railway company or firm of repute, and other things being equal, preference will be given to those who have had experience as Assistants or Journeymen with a railway company.

Final appointment is subject to selected men passing STRICT medical examination.

APPLICATIONS, giving Candidate's age; whether married (if so, what family) or single, and full particulars of career, with dates and names of firms by whom employed to present time, must be addressed to MESSRS. RENDEL, PALMER AND TRITTON, 12-14, Dartmouth Street, Westminster, S.W. 1., Consulting Engineers to the Railway Companies concerned, not later than 17th March next. Where so requested, applications will be treated as confidential.

NOTE.—Replies will only be sent to such men as may be considered for appointment to the present vacancies, but all applicants should, wherever possible, give a permanent address, because if not dealt with immediately, they may be considered suitable for future vacancies. All letters should be marked outside "APPOINTMENTS." S 980

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THE MEASUREMENT OF FLUID VELOCITY AND PRESSURE.

By J. R. PANNELL, A.M.I.M.E., F.R.Ae.S.

IN general, problems connected with the relative motion of fluids and solid bodies may be divided into two classes, viz., those in which the fluid is in motion, the body remaining at rest, and those in which the principal motion is that of the body. The former class includes the study of the motion of natural winds, and the transmission of fluids in pipes, while in the latter we may place problems relating to the motion of aircraft or naval vessels.

When it is desired to reproduce these conditions for experimental investigation, it is usual, except in the case of aircraft models, to set up the relative motion in the same way as under the original conditions. Experimental work on the resistance of ships is carried out mainly by towing models through water in a ship tank, the speed being readily determined by observations of time and signals from the track which indicate the passage of the towing carriage over measured distances. On the other hand by far the larger number of experiments carried out on aircraft models are made in a wind channel where the fluid is in motion while the model remains at rest. This plan offers many advantages over the method of moving the model through the fluid at rest, particularly in connection with the construction of the apparatus and the measurement of the forces acting upon the model. If it be conceded that for uniform motion in a straight line, the conditions are the same whether we move the body or the fluid, the only important respect in which the moving fluid method is at a disadvantage is in the estimation of velocity.

The measurement of the velocity of fluids presents a problem entirely different from that which occurs in the case of the motion of a solid body through space. Fluids are not in general visible in such a manner as to render possible the determination of velocity directly from measurements of time and space, though this method is adopted to some extent in gauging rivers. For determinations of velocity near the surface of a river a surface float is timed over a known distance, while for taking measurements at various depths sub-surface floats are employed, which are attached to very small floats at the surface to render their motion visible. With this exception the most direct case is perhaps that of a liquid flowing in a pipe or channel, where the weight of liquid passing in a given time can be observed. The mean velocity across a section can then be readily calculated if the density of the liquid and the cross-sectional area of the stream are known. Except in an instance of this kind, or in the rare case where a solid body borne along with the fluid can be timed over a given distance, the measurement of the velocity of fluids is generally effected by either one of the following methods:—

(1) Pressure-tube instruments in which the velocity is deduced by measurement of a difference of pressure between apertures in different parts of the apparatus. A separate manometer is required with these instruments.

(2) "Moving part" instruments, in which the velocity is determined either by the steady displacement of some part of the instrument or by the integration of the distance travelled in a given time by some part of the instrument which is free to move without any controlling force.

(3) Hot-wire instruments, in which the velocity is determined from the convection of heat from an electrically heated wire. These instruments are only used for gaseous fluids.

In the great majority of cases measurements of the velocity of *liquid* fluids are made by means of instruments in class (1).

Instruments of class (1) are in general use for scientific work in cases where an accurate measure of the speed is necessary. They are also employed in meteorological work where a record is required of the gustiness of a wind. The principal disadvantages of this class of instrument are the errors which are caused by changes in the density of the fluid, and the necessity for a separate manometer.

Instruments of class (2) which integrate the distance travelled by some freely-moving part have the great advantage that their indications are practically unaffected by changes of density. No separate manometer is required, the velocity being deduced from the instrument reading in a known time. In the displacement type of instrument of class (2) the speed is read off directly from the instrument scale, but the error due to change of density is present in these instruments.

Instruments of class (3) have in the past had a very limited field of application, but they appear to have distinct advantages for certain kinds of work. One of these cases is in the measurement of very low speeds and another when a mean value is required over a certain area.

PRESSURE TUBE INSTRUMENTS. CLASS I.

With very few exceptions every type of instrument, and often every instrument of each type, requires calibration against a standard; one of the exceptions found in this class is the open-ended tube facing the current, in which the pressure has been found to have the value which would have been expected from theoretical considerations for such a tube in a perfect fluid. This tube was used by Pitôt in 1732 for the measurement of the velocity of a river, and was described in a paper read before the French Academy of Science in November of that year.

For calculation of velocity it was necessary to know the height to which the water in this pitot tube (as the open-ended tube is now called) rose above the free surface of the water. To determine the level of the free surface Pitôt used a second open-ended tube which had its axis normal to the current and assumed (though wrongly, as we shall presently see) that the difference of level h of the fluid in the two tubes was the head due to the velocity V, so that V was equal to $\sqrt{2gh}$.

Before considering in detail the reasoning on which the measurement of velocity by means of a pressure tube anemometer is based, it will be well to define clearly what is meant by the "pressure" of a fluid and to explain the term "static pressure," which will be freely used in what follows.

The pressure of a fluid at any point may be defined as the mean of the normal forces per unit area on three mutually perpendicular elements of surface meeting at that point and at rest relative to the fluid.

When a fluid is in motion it is convenient to have an expression to distinguish between the pressure of the fluid as just defined, and any dynamic pressure such as the excess of pressure in a pitot tube above that of the undisturbed fluid. Dr. T. E. Stanton, F.R.S., used the term "static"* to indicate the pressure in a fluid in motion and the expression "static pressure" is now general in aeronautics.

The equation $V = \sqrt{2gh}$ is deduced for the pitot tube on the assumption that Bernoulli's equation for a perfect fluid holds for this tube when it is employed in a viscous fluid. Bernoulli's equation states that (neglecting the energy due to the elevation of the fluid above the datum) the energy per unit volume is equal to:

$$p + \tfrac{1}{2}\rho V^2$$

where V is the velocity, p the static pressure and the density of the fluid. In any section of the fluid over which the energy per unit volume (and consequently $p + \frac{1}{2}\rho V^2$) is constant, we shall have a decrease in V^2 accompanied by a proportional increase in p and *vice versa*, and if we can measure the value of p where the velocity is V and again when the velocity is zero, we can evaluate V. It is this operation which is performed by the pitot and static pressure tubes, for the velocity is reduced to zero at the mouth of the pitot tube and the energy per unit volume of the stream is represented by the pressure in that tube, p_0, while the pressure in the static pressure tube, if it is properly designed will be the static pressure, p, of the fluid moving with a velocity V. If the two tubes are placed at points in the stream where the energy is equal:

$$p_0 = p + \tfrac{1}{2}\rho V^2$$

or

$$p_0 - p = \tfrac{1}{2}\rho V^2$$

where $p_0 - p$ is equivalent to Pit t's h if his second tube read the true static pressure. It should be noted, however, that this equation could only have been confidently expected to apply to a pitot tube in a perfect fluid, and the fact that it does so in a viscous fluid rests entirely on experimental evidence.

A considerable amount of evidence has now accumulated, and it appears that the open-ended tube facing the current (which alone has been named after Pitôt) is thoroughly reliable and may be of widely differing shapes and sizes. The author has compared in a wind channel as pitot tubes, a piece of glass capillary tubing of about 1 cm. external diameter and 2 mm. bore, with a small casting in the form of a cup about 2 in. in diameter at the open end, reducing to 0·5 in. at the after end where the connecting tube was attached. The pressures in the two were found to be identical and to agree with the laboratory standard instrument. In order to determine its absolute accuracy a pitot tube was tested in air by an experiment on the whirling arm at the National Physical Laboratory in 1912* which showed that over a speed range of 17 ft. to 50 ft. per second the pressure equation was fulfilled to an accuracy of one-tenth of 1 per cent., which was the order of accuracy of the particular test.

In the pitot tube, therefore, we have an instrument whose behaviour accords with that which might have been expected from theoretical considerations and by means of which we can determine the value of $\frac{1}{2}\rho V^2 + p$. It remains to measure p and we have already seen that for this purpose Pitôt used an open-ended tube whose axis was normal to the direction of motion of the fluid. It has been found, however, that a serious error is introduced if the pressure in this tube is assumed to be equal to the static pressure; when an open-ended tube is placed with its axis inclined at an angle of 90 deg. to the direction of the current there is a pressure in this tube which is lower than the static by an amount of the order of $\frac{1}{4}\rho V^2$. A tube arranged in this manner is therefore of little use for measurement of static pressure, even if it were calibrated against a standard, since it would be extremely sensitive to change of angle.

A device similar to that of Pitôt was used for air currents in Lind's anemometer, which was invented in 1775. It consisted of a glass U-tube of which one end was bent so as to form a pitot tube whose axis was kept always face to wind by means of a vane attached to the U-tube. The other limb of the tube was cut off horizontally, and no doubt experienced a suction when the wind blew, though it appears to have been assumed at that time that the tube gave the static pressure of the air. The tube was filled with water to a zero mark and the displacement of the surfaces gave a measure of the wind speed. One of the disadvantages of this device (which was not present when similar apparatus was used for water by Pitôt) is the extremely small reading obtained for ordinary wind speeds owing to the density of the measuring fluid (water) being nearly 820 times that of the fluid whose motion is under consideration.

A satisfactory means of measuring static pressure was found by Darcy as long ago as 1854.† He carried out a very extensive series of measurements on the frictional resistance to the flow of water in pipes (actually the water mains of Paris) and used a hole in the wall of the pipe as a means of measuring the static pressure. This method is entirely satisfactory if the measurements are made at a sufficient distance from the inlet to the pipe and all burrs thrown up in drilling the static pressure hole are carefully removed. The same plan was followed in the work which has been carried out by Dr. Stanton and the writer at the National Physical Laboratory, on the flow of fluids in pipes.‡

In 1903 Stanton devised a new type of static pressure tube§ for use in his wind channel experiments on the resistance of plane surfaces in a current of air. The pitot and static tubes were about 0·15 in. in diameter, and they were arranged with their centre lines 2 in. apart. The static pressure tube terminated in a fine point facing the stream, the

* Proc., Inst. Civil Engineers, 1903-4, vol. clvi, page 82.

* Report of Advisory Committee for Aeronautics, 1912–13, page 35.

† *Comptes Rendus de l'Academie des Sciences*, vol. xxxviii, page 407.

‡ Phil. Trans. Roy. Soc., A., vol. ccxiv, page 199.

§ Proc. Inst. Civil Engineers, vol. clvi, page 7.

curved portion being about seven tube diameters in length. At a point 10 diameters from the extremity of this tube four holes were drilled 0·02 in. in diameter, care being taken to remove the burrs which were thrown up in drilling.

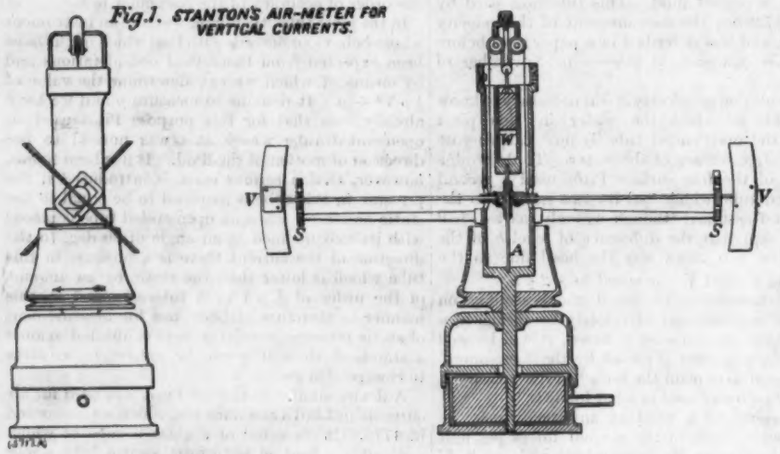
Dr. Stanton calibrated these tubes by means of a very ingenious piece of apparatus, which is shown in Fig. 1. It consisted of two helical aluminium vanes V, attached by means of light arms to a sleeve accurately balanced by a weight W for motion in a vertical plane. These vanes were set at an angle of 45 deg. to the vertical in such a manner that the projection of one vane on the other formed an angle of 90 deg. with it. Helical guides were fitted near each vane and arranged so that if the vanes moved up or down they were constrained to do so along paths normal to their helices. The sleeve to which the vanes were attached was rotated at various speeds by a belt from an electro-motor outside the channel, arrangements being made for rapid estimation of the speed of rotation.

pressure tube 0·30 in., and the diameter of the mouth of the pitot tube 0·16 in. The change in diameter is effected by a gradual taper and the static pressure holes are drilled in the parallel tube 1·8 in. (6 diameters) from the mouth of the pitot tube. The number of static pressure holes is 21 and their diameter 0·040 in. The construction of the tube will be sufficiently obvious on reference to the figure; a soldered joint could be avoided by bending both tubes where they turn normal to the direction of flow. If a head of this kind is in constant use it should be tested occasionally for leaks, both between the tubes and to atmosphere.

Experience has shown that these pressure heads can be constructed and relied upon to give a pressure difference of $\frac{1}{2}\rho V^2$, though it would provide a useful check, if more than one instrument is being made, to test one tube against another, agreement in their readings being taken as an indication that the constant for each is unity. A large head of this type has been constructed at the National Physical

at the top of a closed tank, and after passing an arrangement of baffle plates escapes through an orifice at the bottom; a graduated gauge glass is provided at one side of the tank, and the pressure is measured by reading off the height of the water in this tube. The size of orifice in the meter used by Stanton and the writer could be varied from 0·25 in. to 1·25 in., and by choosing a suitable size for a particular rate of flow the level of the water in the gauge glass could be adjusted to lie within the range for convenient observation, which had an upper limit about 30 in. above the horizontal plane containing the orifice. A tap is provided at the top of the meter in order that accumulated air may be allowed to escape. The meter was calibrated by direct weighing of the water against time, and it was found, as was expected, that the head in the gauge glass varied approximately as the square of the mean velocity through the orifice. This relation was not, however, accurately true, and the author hopes at some future date to publish these

Fig. 1. STANTON'S AIR-METER FOR VERTICAL CURRENTS.



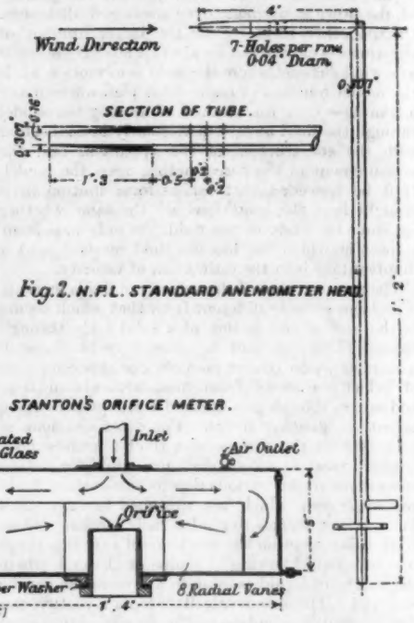


Fig. 2. N.P.L. STANDARD ANEMOMETER HEAD.

Fig. 3. STANTON'S ORIFICE METER.

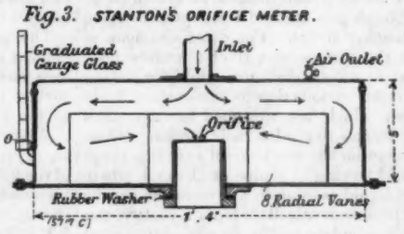
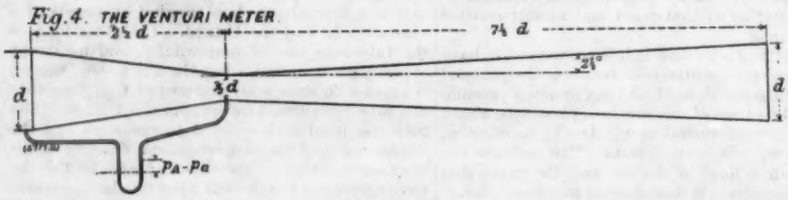


Fig. 4. THE VENTURI METER



If, now, the air-meter be placed in a current of air flowing vertically downwards (as in Stanton's channel), and rotated in the appropriate direction at such a speed that the linear velocity of the vanes is equal to the velocity of the air current, the direction of motion of the air relative to the vanes will be tangential; the force will be normal to the guides and the vanes will remain balanced. A lower rotational speed will cause the vanes to fall and a higher one will cause them to rise. This instrument was found to be very sensitive, a small change in speed causing the vanes to move along their helical paths. By this means the value of K in the equation:

$$V = K\sqrt{\frac{2p}{\rho}}$$

was found to be 1·03, but subsequent calibration on the whirling arm showed K to be unity to an accuracy of one-tenth of 1 per cent. Subsequent experience has shown the accurate determination of air speed to be a matter of considerable difficulty, and in view of the very early stage in the development of aeronautical research at which Stanton's experiments were carried out, his measurements of speed with an accuracy of 3 per cent. must be regarded as very satisfactory. It was afterwards found convenient to make the pitot and static pressure tubes concentric, and a head of this kind (Fig. 2) has been adopted as the standard instrument at the National Physical Laboratory. In this standard head the length of tube parallel to the stream is 4 in., the external diameter of the static

Laboratory and fitted with a vane for use in a natural wind. It is necessary in this case to have a sliding joint in each tube which greatly enhances the possibility of a leak between the two. Calibration in the wind channel showed the head to agree with the standard, and it is now being tested in natural winds under the direction of the Meteorological Office. It appears that the necessary condition for measurement of static pressure is obtained if the lines of flow of the fluid are straight and parallel to the solid boundary in which the static pressure holes are drilled. The two important features which must be observed for this condition to be realised in the National Physical Laboratory head are, that the static-pressure holes must be sufficiently far along the parallel portion of the tube, and that all burrs thrown up in drilling are carefully removed. This instrument furnishes a convenient standard for measurement of the velocity of fluids, either liquid or gaseous, which are clean and not too viscous.

Before passing to a description of instruments of this class designed almost exclusively for use with air we may notice two forms of water meter.

Stanton's Orifice Meter.—A useful form of water meter for laboratory purposes is that shown diagrammatically in Fig. 3; it was used by Stanton in his experiments on heat transmission, in 1897,* and was subsequently employed by Stanton and the writer for similar work in 1914.

The water is supplied to the meter through a tube

* Phil. Trans., Royal Society, A. vol. cxc, page 72.

calibration figures and show that the results for the different orifices may be compared on a basis deduced from the principle of dynamical similarity.

The Venturi Meter.—A simple device which has been used very extensively for water flowing in circular pipes is that known as the Venturi meter; it was invented in 1881 by Clemens Herschel, and is shown diagrammatically in Fig. 4. This meter requires calibration, but the conditions under which it works are well understood, as it depends for its action on Bernoulli's theorem.

If the potential energy of the stream is constant we have $p/W + V^2/2g = a$ constant, where p is the pressure, W the weight per unit volume of the fluid, V its velocity, and g the acceleration due to gravity; the first term is the head representing the pressure energy and the second that corresponding to the kinetic energy. Calling the cross-sectional area of the pipe A and that of the throat a, and neglecting the loss due to friction, we may write:

$$V_A = \sqrt{\frac{2g(p_A - p_a)}{W\left\{\left(\frac{A}{a}\right)^2 - 1\right\}}}$$

In practice allowance is made for frictional losses by placing a constant before the square root, and it is this constant which must be determined by experiment. The dimensions commonly in use are shown in the figure and were given by Gibson, who states that the value of the constant varies from 0·94 to unity, the majority of tests giving values between 0·96 and 0·99. In order that the loss due to friction shall be small this meter should only be used for large pipes, and the surface should be as smooth as possible. The pressure difference

($p_A - p_a$) may be measured on a mercury U-tube or an inverted water U-tube; for very small pressures a three-liquid National Physical Laboratory manometer (to be described later on) would be suitable. Satisfactory apparatus has also been constructed for recording continuously the variations of pressure against time.

The Dines Anemometer.—One of the oldest and most extensively used pressure tube anemometers is that known as the Dines tube. This head was designed by Mr. W. H. Dines in 1862* for measuring the velocity of a natural wind, and a typical instrument of modern type is shown in Fig. 5. The head consists of a pitot tube, which is set to the wind by means of a vane, and a suction tube the pressure in which is not affected by variations of wind direction in a horizontal plane. Two concentric tubes having a small clearance between them form the suction side of the head, the outer tube being pierced by a number of small holes into which the wind blows. There is a considerable reduction of pressure in the annular space between the two tubes, the amount being usually such that the pressure difference of about $0{\cdot}7\,\rho\,V^2$, against $0{\cdot}5\,\rho\,V^2$ for the National Physical Laboratory head. It may be seen from the figure that the pitot and suction tubes are quite separate from each other, the suction tube being placed inside a hollow cone; a plate is placed almost in contact with the back of the cone, and a low pressure is produced in the space between the two.

A head of this form, together with an "Ogilvie" head (described below), was calibrated in water in the ship tank at the National Physical Laboratory up to a maximum speed which, comparing on a basis of dynamical similarity and allowing for the fact that the ratio of the kinematic viscosity of air to that of water is about as 14 to 1, was equivalent to more than 200 ft./sec. in air. The heads were also tested in the air channel, and the pressure difference was found to vary as the square of the speed with considerable accuracy over the whole range of the experiment.

Another device by means of which a considerable suction can be obtained is a tube in the shape of a Venturi tube, shown in Fig. 4, the suction hole being drilled at the narrowest section; an ordinary pitot tube which may be placed in the free stream, constitutes the high-pressure tube. An arrangement of this kind is largely used on American aircraft for measurement of velocity, the high pressure difference (about $1{\cdot}5\,\rho\,V^2$) enabling a low sensitivity manometer to be used.

The design of Venturi tubes for measurement of air velocity has been investigated in considerable detail by Toussaint and Lepere*, who describe a double Venturi tube in which a small Venturi tube is placed inside a larger one, the outlet of the small tube being at the throat of the large one. A reduction of pressure below the static of about 17 times $\frac{1}{2}\rho\,V^2$ was obtained by the present writer with such a double tube at 50 ft./sec.; at higher speeds a still larger relative reduction would be obtained. This plan has been extended to the use of three tubes, one within the other. By a suitable arrangement of the Venturi tubes a greater pressure difference can be obtained for a given velocity than by any other apparatus known to the writer. The chief disadvantages of the device are the marked effect of any irregularity or change in shape of the Venturi tube on its calibration, and the variation from the "square law" of the pressure in the suction tube.

As, however, more experience has been gained in the manufacture of air pressure indicators it has been possible to obtain ample sensitivity at normal aeroplane flying speeds and the modern tendency is to revert to tubes in which the pressure difference is $\frac{1}{2}\,\rho\,V^2$. These pressure heads have the great advantage that, if certain simple precautions are observed they can be relied upon to read accurately $\frac{1}{2}\,\rho\,V^2$, and individual tubes do not require comparison with a standard.

A head of this type which has been extensively used is the "Ogilvie," shown in Fig. 7. In this head the static pressure holes are 1·8 in. (3·6 diameters) from the mouth of the pitot tube. Calibration of this head showed that the speed deduced from its indications was about 1 per cent. high, a defect which could probably be remedied by increasing the distance from the mouth of the pitot tube to the static pressure holes to say 2·5 in., (5 diameters). On many aeroplanes at the present day the anemometer heads consist of separate pitot and static pressure tubes placed an inch or so apart and attached to one of the forward struts well clear of the body. It may be noted in passing that no convenient position has been found on an aeroplane in which the head can be placed where it will be unaffected by disturbance of the air due to parts of the machine. The error, which is determined by flying the machine over a measured course, will not in general exceed about 3 per cent. on the speed.

(To be continued.)

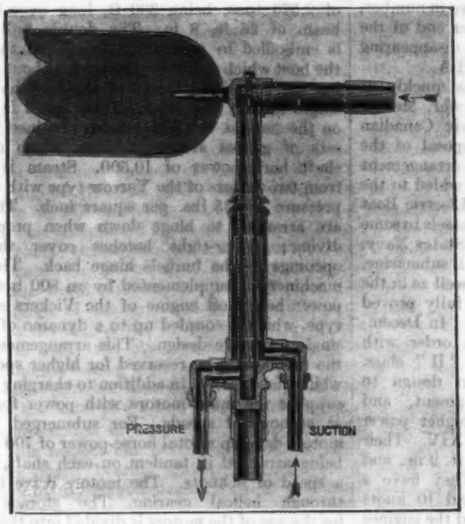


FIG. 5. THE DINES ANEMOMETER HEAD.

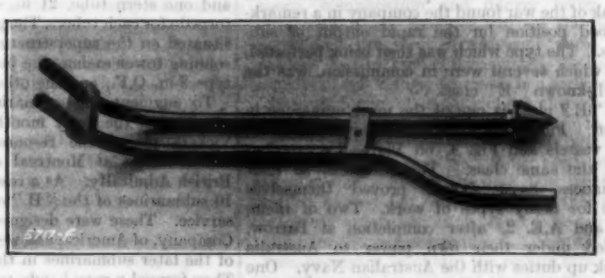


FIG. 6. THE CLIFT ANEMOMETER HEAD.

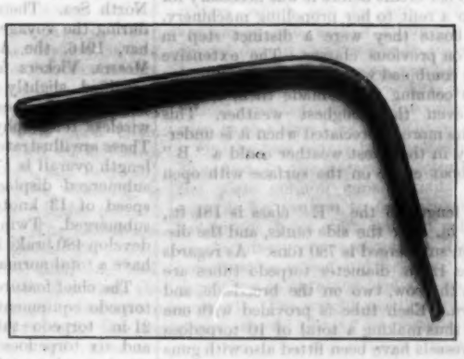


FIG. 7. OGILVIE ANEMOMETER HEAD.

difference for this type of head is some 50 per cent. greater than in the National Physical Laboratory standard anemometer head. This low pressure is not, however, without some disadvantage as the amount of the suction appears to be very sensitive to small changes in the dimensions of the head, particularly as regards the width of the annular space inside the suction tube and the diameter of the holes.

This sensitivity to small variations in dimensions has led to the calibration of the majority of these instruments, and the author understands that a maximum variation of 4 per cent. in the pressure difference at a given speed is tolerated by the Meteorological Office. In the more recent types of head in which the width of the annular space is usually greater than 0·1 in., the heads appear to be reproduced with sufficient accuracy for variations in their calibration to be negligible.

A special recorder (which will be presently described) has been designed for use with this head by means of which a trace is obtained showing a continuous record of the variations of wind velocity, and enabling an estimate of the gustiness to be made.

The pressure tube anemometer has been used in many forms, and a few years ago, when the manufacture of portable indicators was in its infancy it was an advantage, particularly for use on aircraft, if a head could be used in which by means of a suction tube such as that of the Dines head, a greater pressure difference was obtained for a given velocity than in the National Physical Laboratory type of head. For this reason the "Clift" head, shown in Fig. 6, was constructed and gave a pressure

* Quarterly Journal of Royal Met. Soc., vol. xviii, page 168.

* Bulletin de l'Institute Aerotechnique de l'Universite de Paris, Fasc III, 1913.

MAGNET STEELS.—A good deal of research work on magnet steels has been conducted at the Reichsanstalt during the war; only part of it has, so far, been published in the Wissenschaftliche Abhandlungen. One of the points investigated is the substitution of chromium steel for tungsten steel. Bar magnets of chromium steel, stored for a year without being exposed to any disturbance, kept their magnetic moment constant within 0·3 per cent. and less; in all the cases the changes observed were within the limits of the experimental error in the second half of the year. As regards constancy to heat variations and concussions and temperature coefficient the chromium steel proved equal to tungsten steel; in coercive force and remanence the best chromium steel did not come up to the best tungsten steel. The temperature coefficient of the magnetic moment diminishes with increasing content of dissolved carbon and was found to be zero in a 1·4 per cent. carbon steel. To investigate the suitable ratio of length to diameter in the case of bar magnets a chromium steel originally 22 cm. in length and 0·6 cm. in diameter was gradually shortened to a length of 2·4 c.m.; this shortening raised the temperature coefficient from 2·4 per cent. up to 4·2 per cent. The ratio of length to diameter l/d was also found not to be without influence on magnetometer determination of the coercive force. When the value of l/d fell below 10, these determinations gave too low values; practically this point is not important.

BRITISH SUBMARINE BOAT BUILDING DURING THE WAR.

MESSRS. VICKERS' achievement in submarine construction during the war is one of which the firm has every reason to be proud. Fifty-four submarines of all classes have been built and commissioned in a period of fifty-one months of war, and are detailed as follows :—

"E" class	15
"V" class	4
"G" class	6
"K" class	6
"N" class	1
"H" class	10
"L" class	9
Other types	3
Total	54

Of these boats, all except "V" and "N" classes were built to Admiralty design.

These figures are additionally interesting when it is remembered that in practically every class Messrs. Vickers were the pioneer builders. The outbreak of the war found the company in a remarkably good position for the rapid output of submarines. The type which was then being perfected, and of which several were in commission, was the now well-known "E" class.

This "E" class is one of the most numerous in the fleet. Fig. 1, on Plate XIV, shows one of the earlier vessels and Fig. 4, on Plate XV, another ship of the same class. These vessels, as their performances have shown, proved themselves suitable for many types of work. Two of them, A.E. 1 and A.E. 2, after completion at Barrow, proceeded under their own power to Australia and took up duties with the Australian Navy. One of these vessels actually had considerably over 30,000 miles to her credit before it was necessary for her to undergo a refit to her propelling machinery. As sea-going boats they were a distinct step in advancement on previous classes. The extensive superstructure combined with the navigating bridge built over the conning tower made them easy to navigate in even the roughest weather. This advantage is the more appreciated when it is understood that only in the finest weather could a "B" or "C" class boat cruise on the surface with open hatches.

The overall length of the "E" class is 181 ft., beam 22 ft. 7 in. over the side tanks, and the displacement when submerged is 780 tons. As regards armament, five 18 in. diameter torpedo tubes are carried, two in the bow, two on the broadside, and one in the stern. Each tube is provided with one spare torpedo, thus making a total of 10 torpedoes carried. The vessels have been fitted also with guns of various types, but a tabulated statement would be necessary to give full particulars of these.

The radius of action at a cruising speed of 10 knots is 3,225 nautical miles, with a total oil fuel capacity of 42 tons. A surface speed of 15 knots is obtained by twin screws which are each driven by a Vickers' eight-cylinder heavy oil engine of four-cycle vertical single-acting type, each engine developing 800 brake horse-power. The motors, for use when submerged, are of the Vickers' single-armature open type, each developing 420 brake horse-power, and resulting in a speed of 10 knots. The power for the motors is stored in two separate batteries of 112 cells each, constructed by the Chloride Electrical Storage Company, of Manchester. Air storage is provided by 57 bottles stowed about the ship. High-pressure air compressors keep the bottles charged.

To equip these boats for more effective scouting and patrol work, a wireless telegraphy installation is fitted, the aerial being carried on folding masts. In addition, a set of under-water signalling gear is carried. Two periscopes are fitted, one being a simple, single-power instrument, the other being fitted with a device which readily permits of alternative powers of 1 and 6 being used. The latter can also be used as a "sky-searcher" for detecting enemy aircraft.

Messrs. Vickers created a record as regards the building and equipment of the "E" class submarines, E. 19 (Fig. 1) being built, equipped and handed over to the British Admiralty in exactly eight months; whilst a flotilla of six, including the above, was commissioned in thirteen months from the date of verbal Admiralty instructions to proceed with their construction. During the period in which the company were engaged on "E" class construction, they were also devoting considerable attention to a new type of submarine in which the principal idea was the provision of a complete double hull.

The "G" class, illustrated by Fig. 3, on Plate XIV, followed upon the Vickers' "V" design, to which reference will be made later. This is of increased size and armament. The "G" class (of which Messrs. Vickers constructed six) is 187 ft. long, 22 ft. 8 in. beam with a submerged displacement of 840 tons. These dimensions follow the single-hull "E" class very closely, but with increased displacement consequent on the addition of the double hull. The full surface speed of these vessels is 15½ knots, obtained by twin Vickers' heavy oil engines, each developing 800 brake horse-power. The full speed submerged is 10 knots, the motors working at 420 brake horse-power each. The armament of the "G" class consists of two bow and two broadside torpedo tubes, 18 in. diameter, and one stern tube, 21 in. diameter, with a spare torpedo for each tube. The guns are two in number, situated on the superstructure at either end of the conning tower casing, one being of the disappearing type 3-in. Q.F., and the other 2-pdr. H.A.

To augment the submarine fleet as quickly as possible, in the early months of the war, Messrs. Vickers placed the resources of their Canadian establishment at Montreal at the disposal of the British Admiralty. As a result of this arrangement 10 submarines of the "H" class were added to the service. These were designed by the Electric Boat Company, of America, and were sister vessels to some of the later submarines in the United States Navy. They formed a very handy type of small submarine, and did useful work in the Adriatic as well as in the North Sea. Their seaworthiness was fully proved during the voyage across the Atlantic. In December, 1916, the Admiralty placed an order with Messrs. Vickers for 12 boats of the "H" class, modified slightly from the American design to accommodate heavier torpedo equipment, and wireless telegraphy gear of a much higher power These are illustrated by Fig. 2, on Plate XIV. Their length overall is 171 ft. 9 in., beam 15 ft. 9 in., and submerged displacement 510 tons. They have a speed of 13 knots on the surface, and 10 knots submerged. Twin screws are fitted, and the engines develop 480 brake horse-power. The electric motors have a total normal shaft horse-power of 640.

The chief feature in this class is the very powerful torpedo equipment in relation to their size. Four 21-in. torpedo tubes are arranged in the bows, and six torpedoes are carried. As in the case of previous classes Messrs. Vickers were entrusted with the first boat of the "H" class, the experience of their designing and constructive staffs making them eminently suited for pioneer work of this kind.

A class of "J" boats were built in the dockyards, and had each three sets of Diesel engines by Messrs. Vickers. These were the fastest heavy oil-engined vessels in the world.

The "L" class combines in design the best qualities of other boats, but with increased speed. The "L" class with others are shown in the engraving, Fig. 5, on Plate XV. These three vessels were delivered simultaneously—an incident which brought to the firm a special note of congratulation from the Admiralty.

The circular single hull is used with the side tanks as in the "E" boats, but the stern is a modified and improved arrangement of the stern fitted in another class. The length overall is 238 ft. 6 in., being 57 ft. longer than the "E" class. The beam over the side tanks is 23 ft. 6 in., and the total submerged displacement is 1,090 tons. The Diesel machinery is of a more powerful type than previously fitted. The twin screws are worked by four-cycle, 12-cylinder oil engines and develop a total of 2,600 brake horse-power, which results in a surface speed of over 17 knots. Motors for submerged running are fitted to both shafts, and on a total brake horse-power of 1,600 a speed of 10½ knots can be maintained. The auxiliary machinery includes two high-pressure air compressors of the inverted water-cooled type, each capable of delivering per hour 22·5 cub. ft. of air compressed to 2,500 lbs. per square inch.

The torpedo equipment in this class consists of four 21-in. tubes in the bows, and two 18-in. tubes in the broadside room, with a spare torpedo for each of the tubes. A 4-in. gun is mounted on the superstructure just forward of the bridge and conning tower. Very large angles of training are obtained by the use of a revolving platform which moves with the gun. A novel feature is the night periscope which is fitted in addition to the ordinary instruments. This enables the boat's crew to keep a more effective watch at night.

As the submarine requirements of the Allied Grand Fleet increased, it became necessary to have a type which, whilst still retaining the ordinary functions of the submarine, could yet maintain its station with the fleet when cruising. These requirements were embodied in the design of the "K" class, of which Messrs. Vickers were entrusted with the first ship of the type, and also five others. The class is illustrated by Figs. 6 and 7 on Plate XVI, the latter view showing K 3 steaming at full speed. These vessels have a displacement when submerged of 2,570 tons, being 339 ft. long overall, with a beam of 26 ft. 8 in. The double hull principle is embodied in a modified form, and the ends of the boat which might be damaged without endangering the immediate safety of the boat have only a single hull at the sides. Their speed is 24 knots on the surface, the power being obtained from twin sets of geared steam turbines, which develop a shaft horse-power of 10,500. Steam is obtained from two boilers of the Yarrow type with a working pressure of 235 lbs. per square inch. The funnels are arranged to hinge down when preparing for diving; water-tight hatches cover the funnel openings as the funnels hinge back. The turbine machinery is supplemented by an 800 brake horse-power heavy oil engine of the Vickers submarine type, which is coupled up to a dynamo of the open single armature design. This arrangement enables the turbines to be reserved for higher speeds only, whilst the dynamo, in addition to charging batteries, supplies the main motors with power for cruising at economical speeds. For submerged work the motors develop a total horse-power of 700 per shaft, being arranged in tandem on each shaft, and give a speed of 9 knots. The motors drive the shafts through helical gearing. The storage battery for the use of the motors is divided into three groups of 112 cells per group.

Owing to the very exacting duties required of these boats, additional protection for the navigating officer and quartermaster is provided in the form of a deckhouse built over and around the ordinary conning tower. The periscopes fitted into these boats were the longest which at that time had been made for the British Navy, having a length of 30 ft. from eye-piece to head-piece. Another important accessory is the long-distance wireless telegraphy installation, enabling the commander of the submarine to keep in touch with his naval base when operating at great distances from it. The aerial is carried on telescopic masts, which can be raised and lowered at will. The air compressing machinery consists of two low-pressure and two high-pressure air compressors, with air bottles stowed in various positions about the vessel contiguous to their work. A telemotor system is installed for raising the periscopes and telescopic masts, and also for working the ballast tank vent valves.

The armament of this class includes four bow and four broadside tubes, all 18-in. diameter, with a spare torpedo for each tube. The guns are carried on the superstructure and consist of two 4-in. guns and one 3-in. gun for high-angle work.

These vessels are a departure from the ordinary type in that they are self-contained units of the fleet, and do not rely upon a parent ship as is the case of "E" and other classes. Their performances during the war have been of the greatest value to the naval authorities, their speed, armament, and low visibility making them exceedingly useful additions to the British Navy. It is interesting to note that this class of submarine is, for surface work, the fastest in the world.

The other vessel illustrated on Plate XVI is the

"V" class (Fig. 8). This type was introduced at an earlier date as a result of tank experiments by Messrs. Vickers in which several forms of hull were tried. Four vessels of the "V" class were ordered by the Admiralty from the firm. The principal dimensions are length overall 147 ft. 6 in., beam of outer hull 16 ft. 3 in., and submerged displacement 460 tons. Twin sets of Vickers heavy oil engines are fitted developing 450 brake horse-power each, from which a surface speed of about 13 knots is obtained, the engines being of the four-cycle vertical single-acting type with eight cylinders. When submerged a normal full speed of 8½ knots is obtained from two motors each developing 190 brake horse-power. The storage battery consists of 132 cells arranged in two groups of 66 cells each. The torpedo equipment of these boats consists of two 18-in. diameter bow tubes and two spare torpedoes.

Minelaying submarines are a logical outcome of the war, and several of the "E" and "L" classes were equipped as such. The mines are loaded into vertical tubes which pass through the external tanks. Mechanical gear is fitted for both locking the mines in position and for releasing them when required.

On Plate XVII we give engravings of two typical Vickers' heavy oil engines, built for submarine boat propulsion. Fig. 9 illustrates an eight-cylinder reversing engine, and Fig. 10 a 12-cylinder non-reversing, as used in many British submarines. This latter is a development of the six and eight-cylinder engines fitted in "D" and "E" boats, and in its details embodies the requirements of the service as ascertained by years of hard sea use.

The Vickers' engine being the standard for the British boats, the existence of spare gear stocks all over the world prevents any radical departure in the design of the principal parts, but nevertheless, in developing the reversing design, it was possible to make the main parts interchangeable with the non-reversing type, and at the same time to make the weight less than that of the non-reversing engine of the same power and cylinder dimensions.

The construction of both engines is similar, so that in this respect one description suffices. The cast steel main bearing girders are connected longitudinally by forged beams. There are plate columns between the cylinder covers and the main bearing girders to relieve the cylinders of all vertical stress.

A cast-iron liner is dropped into a sandwich plate between the covers and columns, and is thus free to expand downwards. A jacket of steel plate, corrugated for expansion, is fixed to the sandwich plate at the top, and is fitted with a sliding joint at the bottom between the jacket and the liner. Thrust reactions are taken by snugs butting against the bottom of the liner where it passes through the top plate of the crank-case. This top plate serves to tie the columns together.

The cylinder covers are of cast steel of simple construction, secured to the sandwich plate and to the columns. The joint is made by a cast-iron ring ground into grooves in the liner and in the cover. Water connections between the jacket and cover, consist of tubes through the sandwich plate, passing into holes in the bottom of the cover, water-tightness being secured by soft packing rings around the tubes. No submarine engine cover has been known to fail in a Vickers' engine.

The valve boxes are separate from the cover, and are fitted upon coned seats in recesses in the cover. The valve boxes are water cooled by water from the cover. This water, in the case of the exhaust valve, passes into the jacket of the exhaust bend. The valves are of nickel steel, and the exhaust valve is water-cooled through flexible hoses. The piston is of cast-iron, with six upper rings and one wiper ring. They are non-water-cooled. An aluminium guard is fitted above the gudgeon to prevent oil splashing upon the crown. The connecting rod is hollow, of round section, with separate bottom end and compression liner. The crank is closed by portable sheet casings, and is ventilated by suction pipes to the induction header, non-return valves being fitted in the suction pipes to eliminate any possibility of a backfire into the crank-pit. The above-named features are common to both engines.

We come now to points of difference between the two engines. The 12-cylinder engine has the inlet and exhaust cams on a lower camshaft actuating the valves through push rods. The upper camshaft carries the fuel cams and drives the fuel injection pumps, one to each cylinder. This separate pump design is that originally preferred by the Service, but the spray valves have proved themselves such accurate means of regulating the fuel injected that a common fuel supply is now finding favour, and this is fitted in the reversing design. In this latter case the fuel is pumped into a common main from which are branches leading to the separate cylinders. No gags are required, as for air injection engines with a common fuel supply. This common supply pump is a four-throw pump driven by spirals from the end of the crankshaft. In the 12-cylinder engine the pump discharges may be connected at will, thus resulting in running on the "common rail" system as used in the eight-cylinder engine shown. The use of the common pump permits of one camshaft only in the reversing design. This shaft carries all cams, the air-starting cams being at the ends of the engine. The short push rods for the inlet and exhaust rods are pulled away from the cams by the rotation of a fulcrum shaft, after which the camshaft is slid longitudinally, and the push rods are then replaced upon the cams for running in the opposite direction. The fuel and air cams are bevelled, permitting the camshaft to slide without their tappets being lifted. All reversing is carried out by hand, it being desirable to avoid servo-motor gear, which generally gives trouble after some time at sea.

The 12-cylinder engine has the standard spray valve with external gland. The reversing engine has a flooded valve, in which the spindle does not project through a gland, but is actuated by a bell crank, the rotating shaft passing through a gland in the side of the valve-box. Both types give equally good results, and choice is made according to the case of adaptation to the valve mechanism.

In each case the engine is started by air. The air is admitted in correct sequence by tappet valves with a spring and a balance piston upon them. By this means the valves are lifted off the cams when the air master valve is closed, and they only come into action when starting or reversing is required. The air passes to each cylinder through a non-return valve on the cover. The mechanical injection is so safe in its operation that there is no necessity to shut off air before admitting fuel. In the reversing engine it is arranged that the starting wheel shuts off air when all cylinders are on fuel, but in the non-reversing type the two are not interconnected. No cylinder relief valves are necessary for these engines, although in the reversing engines, such are fitted to comply with the standard specification. The fact that the British submarine engine has no cylinder relief valves is practical evidence of the strength of the parts and of the safety of the injection system.

The control is different in the two engines. We may describe first that of the 12-cylinder engine. One hand wheel in the centre controls the opening of all of the spray valves. Individual cylinders can be put in or out of action by the handles at each cylinder. A second hand wheel controls the output of the fuel pumps by sliding a shaft upon which stirrups moving the scroll cams actuating the suction valve of each pump are mounted. The horizontal wheel advances or retards the injection by moving vertically a coupling in the vertical shaft. This coupling is free to slide vertically on one part of the shaft, but drives the other through inclined keys. By this gear the upper camshaft can be rotated a few degrees relatively to the crankshaft. This gear is a refinement, enabling the spray cams to be set with great convenience to meet any conditions of fuel or load-speed ratio, which may vary considerably in a submarine charging when running on the surface, and it is not fitted to the reversing engine in which the duration of the injection is so related to the first instant of injection throughout the range of control that automatic regulation sufficient for satisfactory running in all ordinary conditions is obtained. An emergency stopping valve is also fitted to the 12-cylinder engine, which releases the pressure from the rail.

The eight-cylinder engine control may now be described. The large hand wheel seen in the view is for reversing, and a small hand wheel interlocked with the first wheel first admits air to all cylinders, then fuel to four cylinders, then fuel to the second four, and shuts off air. A further turn stops the engine by shutting off fuel. The pump output is controlled by a small lever regulating the closing point of the suction valves. The large upper lever controls the spray valve opening.

All cylinders in both engines are 14½ in. diameter by 15-in. stroke, and each easily develops 100 brake horse-power at 380 r.p.m. Powers up to 50 per cent. in excess of this have been obtained at higher speeds, but a conservative rating has been followed by the Admiralty authorities. It is plain that high ratings must result in reduced durability, and the consistently steady running of the British submarines year in and out appears to point to the soundness of this policy.

The injection is of the Vickers' mechanical system, no injection-air compressor with its weight space, complication and danger being required. Air compressors, however, perfect the design, are considered the most troublesome parts of Diesel engines and in high duty engines, the supply and control of the high-pressure air is a serious problem. The system consists simply of a high-pressure pump supplying the fuel to a main, from which a definite amount is admitted each firing stroke by a measuring valve in the cylinder head, and passes to a simple spraying nozzle. The power is controlled by varying the duration of the opening of the spray valve, and at the same time adjusting the pump to the pressure required. Years of trial have been necessary to obtain the results now given, but in its present development the injection is reduced to the simplest possible terms. The result is a system which can be run with little previous knowledge and with a minimum of attention or danger due to carelessness in adjusting. The consumption per brake horse-power is about 0·4 lb. per hour, figures as low as 0·381 at full power on official trials independently recorded being obtained, even in war time hurry of delivery.

One or two points in the design may be noted. The first is the extreme accessibility gained by the plate column construction. This renders it possible for engines to be maintained and refitted by ship or depot staffs without calling in dockyard or manufacturers' assistance. The second is the conservative rating and stresses. Thereby extreme durability is obtained and serious breakdowns are avoided. The weight per brake horse-power of an engine should always be considered in connection with the rating and stresses allowed. The Vickers' construction is in principle a very light one, and even with the low rating results in a weight per brake horse-power of 58 lb. for the bare engine, calling the power 1,200 for the 12-cylinder engine. This weight is reduced to below 50 lb. if the power be taken as 1,400 h.p., which is easily obtained, and would be very materially decreased if the piston speed were increased to the high figure of 1,323 ft. per minute, as is obtained in some of the German "U" boat engines. The third notable feature is the avoidance of special methods of manufacture. While the best material and workmanship are used, special steels are avoided, as also are heat treatment of details and parts requiring very special tools or processes of manufacture. Thus spur wheels are used wherever possible in preference to spirals. The engine thus becomes an ordinary manufacturing and refitting proposition, and no danger arises if a broken part is replaced in ordinary material. Such a policy permits boats to be sent to foreign stations with more assurance than if they were dependent for upkeep upon expert supervision during repair.

Finally, are simplicity and safety. All adjustments are obvious and readily carried out, and the abolition of the air compressor renders the engine particularly simple to understand and to run.

The main propelling machinery of the "K" boats consists of two sets of single reduction geared steam turbines and two boilers of the straight-tube three-drum type, having a working pressure of 235 lb. per square inch and arranged for burning oil fuel. Each set of turbines consists of one high-pressure

and one low-pressure cylinder, both turbines driving the main line of shafting by double helical gearing. An astern turbine is incorporated in each low-pressure turbine. The full power ahead shaft speed is 400 r.p.m., the corresponding turbine speeds being, high pressure 3,500 and low pressure 2,800. The main motors, which are in the wings of the ship, somewhat above the shaft centres, are also connected to the propeller shafting by double helical gearing, the ratio in this case being 2 to 1. The turbines can be declutched from the line of shafting when desired, while clutches are also fitted between the main motors and the shaft line. This latter set of clutches must be disengaged when the main shaft is running at above 220 r.p.m., and this unclutching is carried out by hand or automatically by governor gear. The turbines are installed in a separate compartment, watertight bulkheads being provided at the forward and after end of the compartment, with two doors in the former, one for access to the boiler room and the other to the main passage way to the forward part of the vessel; and one door in the aft bulkhead leading to the motor room.

The boiler room contains, in addition to the boilers, the feed pumps, oil-fuel pumps, heaters and filters, and forced-draught fans, the latter being driven by impulse steam turbines. A hinged funnel is provided for each boiler, arranged so that it may be lowered into the superstructure and the opening closed by a strong steel cover, both operations being performed simultaneously by means of an electric motor placed in and operated from the turbine room. In later boats a hydraulic semi-rotary engine is used. As a precaution against accident in the event of the funnel covers being damaged, an additional valve of special design is fitted on the hull of the vessel at the base of the funnel uptake. The covers for making watertight the air vents in the boiler rooms are hydraulically operated from the boiler room. In later boats of the class these covers are in duplicate. Arrangements are provided for shutting off the supply of oil fuel to the boilers before the funnel opening can be closed. The turbines, boilers and all hot surfaces are carefully and thoroughly lagged with incombustible, non-conducting material, with the object of reducing the temperatures in the engine room and boiler room to a minimum, and an efficient system of ventilation is provided throughout the machinery compartments.

For cruising, it is possible to use an eight-cylinder, 800 brake horse-power oil engine of the submarine type. This engine drives a dynamo which can be used for charging the batteries and for driving the ship at cruising speed by electrical transmission to the main motors. The auxiliaries for the oil engines are on the same lines as those fitted in ordinary submarine practice.

The auxiliary machinery in the ship is of the usual pattern for submarine service, though somewhat larger in cases. Two compressors are fitted for charging the 2,500 lb. high-pressure air bottles, of which over 100 are fitted in the vessel. One of these compressors is motor driven and the other is direct driven from the end of the generator shaft. Two low-pressure air compressors are fitted for supplying air for blowing the water from the main ballast tanks when the vessel has broken surface. Two three-throw double-acting reciprocating bilge pumps, driven by electric motors, are also fitted for pumping the tanks and bilges. The telegraphs are of the ordinary mechanical type fitted with electric bell replies.

A special feature of these boats is the fitting of hydraulic power for various operations, such as working vent valves in the ballast tanks, air intakes in the boiler room, and the raising and lowering of the periscope rams and wireless masts. In the later boats this system is also applied to the funnel covers. The steering gear, and also the forward and after hydroplane diving gears, are operated by means of motor-driven Variable-Speed Gear Company's hydro-electric units, one for each service, controlled from pedestals placed in the control room. Hand gear is fitted in each case for emergency use. The steering gear itself is of the usual submarine screw-gear type.

The forward hydroplanes are of the housing type, the planes sliding inboard along the shaft into the superstructure to protect them from heavy seas and during high-speed running on the surface. This operation is effected by hydraulic power, but hand emergency gear is also fitted.

The torpedo equipment of these vessels consists of four 18-in. torpedo tubes in the bow and four 18-in. broadside tubes. In later boats of the class the bow armament equipment consists of six 21-in. torpedo tubes.

This history of submarine boat and engine design and construction when carefully examined, shows that the underlying principle has always been the carrying of weapons of offence. The torpedo is the weapon which has naturally developed as the submarine's particular equipment on account of the ease of firing when the boat is either submerged or awash. But guns of increasing calibre are being adopted.

EARTHQUAKE WAVES AND THE INTERIOR OF THE EARTH.

Earthquakes are violent disturbances of the Earth supposed to originate in an Earth's crust, not more than 40 miles in thickness probably, at some unknown depth below the so-called epicentre. The earthquake waves set up may travel in all directions by various paths, either keeping near the surface in arcual paths, or passing more or less straight through the centre along chords; hence arcual and chordal distances are distinguished. Many earthquakes seem to originate in the sea near coastal ranges; they are believed to be connected with geological faults. From the intensity and peculiar character of the local destruction the origin or epicentre may sometimes be established with fair certainty; at different stations the earthquake rays arrive at different times, and observations are made mostly with the aid of pendulums of the horizontal and vertical types. As a rule two horizontal booms are set up, one in the east-west, another in the north–south direction, so that the N–S and E–W components can be separately determined. Such a boom hardly ever keeps quiet, and its trace hence is not a straight line. For the Earth's crust is constantly disturbed, by big concussions somewhere which are felt all over the globe, or by minor subsidences, rains, heat, or merely the traffic.

When an earthquake curve or seismograph is examined we can generally distinguish two parts in the seismograph, the preliminary tremor and the large wave; these terms are due to the pioneer of earthquake study, the late John Milne. Thus there are two beginnings in the curve; but they are by no means always distinct. Milne first pointed out that the length of the preliminary tremor P T increased with the distance from the origin. In some cases the distance corresponding to a P T lasting 4 minutes, *e.g.*, was actually known; when in another case a P T of 4 minutes was observed at A, the origin would be somewhere on a circle described about A with a radius of that distance; when similar observations were available from B, the two intersections of the two circles would give two possible origins. In the most perfect instruments of the late B. Galitzin the E–W and N–S components appear on the same sheet, and the vertical component of the movement is also recorded; in that case the study of the three curves obtained at one station is sometimes sufficient to determine the origin. But the interpretation of the curves is very difficult; the determination of the angle of emergence of a wave cannot be made with accuracy, the vertical component can hardly be separated from the horizontal movement, and hence the observational basis for the study of the propagation of earthquake waves is very uncertain. That study has, however, a great interest because it is practically the only research which promises to give us some information about the interior of the Earth; our mine shafts and boreholes hardly penetrate more than 1 mile into the crust of the Earth. It is with this problem that Professor Cargill G. Knott, D.Sc., general secretary of the Royal Society of Edinburgh, dealt in his Royal Institution discourse on "Earthquake Waves and the Interior of the Earth" on Friday, the 14th inst. Professor Knott was with Milne in Japan; he conducted the magnetic survey of Japan in 1887, and has been connected with seismic research ever since those days, rather as a mathematical physicist than as an observer, however.

In the seismographic records of large earthquakes, outside their areas of large destruction, two phases can generally be distinguished in the preliminary tremor, Professor Knott pointed out, the primary phase P and the secondary phase S. In the large wave following the tremor various scientists further distinguish other phases; Omori, *e.g.*, speaks of five phases. But the Japanese differ from most of the European scientists in their assumption that the waves all keep within the crust, whilst Professor Knott assumes vibrations of three kinds, only one of which (the large wave) travels in the crust, whilst the other two (the P and S) pass through the body of the Earth. In his lecture Professor Knott referred chiefly to the P and S phases. We imagine light to be propagated along the shortest paths in straight lines; a falling body also takes the shortest straight-line path, but when forced to follow an oblique path it travels quicker on a cycloid than on a straight line. Professor Knott's analogue of the cycloid in the propagation of earthquake rays is the brachistochronic path, *i.e.*, the path of shortest time; the form of this path depends upon the manner in which the density and elasticity of the Earth vary with the depth below the surface. We know nothing as to the law of variation of this elasticity and density; we can make assumptions, but the mathematical solutions of the formulæ deduced are exceedingly complex, and none of the assumptions made have proved satisfactory. Professor Knott explained how he had, on Hamilton's integral theory, been able to draw certain conclusions as to the interior of the Earth from the interpretation of seismographs without having recourse to any basal assumptions.

When a rope was pulled, Professor Knott remarked, a compressional longitudinal wave travelled up and down the rope; when a twist was given to the free end of the rope, another distortional or transversal wave was set up. The same types of waves had to be distinguished in any elastic medium; the acoustical waves were of the compressional or condensational type, sound being propagated by a series of condensations and rarefactions. The velocities of propagation of the two waves depended upon the density d of the medium and its two elastic constants or moduli, the incompressibility or resistance to compression k, and the resistance to shear or kinetic rigidity n. In the case of the distortional wave the velocity of propagation was simply $v = \sqrt{n/d}$; for the compressional wave the formula was more complex, and the velocity $V = \sqrt{(k + \frac{4}{3} n)/d}$. Thus the square of the velocity always depended upon the elastic constants and the density; but for the compressional wave both the constants had to be considered, and the V was always greater than the v. The surface waves (the large waves) were not reducible to such simple expressions because they were not purely elastic, gravity, flexual rigidity and viscosity of the inhomogeneous crust being also determining factors. But for the waves travelling through the interior the simple formulæ might be believed to hold. Assuming now that the P and S waves of the preliminary tremor were propagated as elastic waves through the body of the Earth along brachistochronic paths, Professor Knott, about 1905, analysed the seismic radiations supposing the source of the disturbance to be close to the surface of the globe and that the speed of propagation would vary only with the distance from the Earth's centre. In that case, he found, the waves of highest speed seemed to traverse the main (inner) body of the Earth with a uniform velocity of 12·2 km. per second, but that velocity diminished gradually down to 6 km. within the crust (of a thickness of about one-tenth the Earth radius, 6,380 km.) surrounding the nucleus. A still better agreement between the observational data and deductions would have been obtained by assuming two layers in the nucleus in addition to the crust. But the results were not really satisfactory, and two years ago, therefore, Professor Knott started, in conjunction with Professor Whittaker, on a very laborious calculation

THE ERITH-RILEY MECHANICAL STOKER.

CONSTRUCTED BY THE ERITH ENGINEERING COMPANY, LIMITED, LONDON.

(*For Description, see Page* 268.)

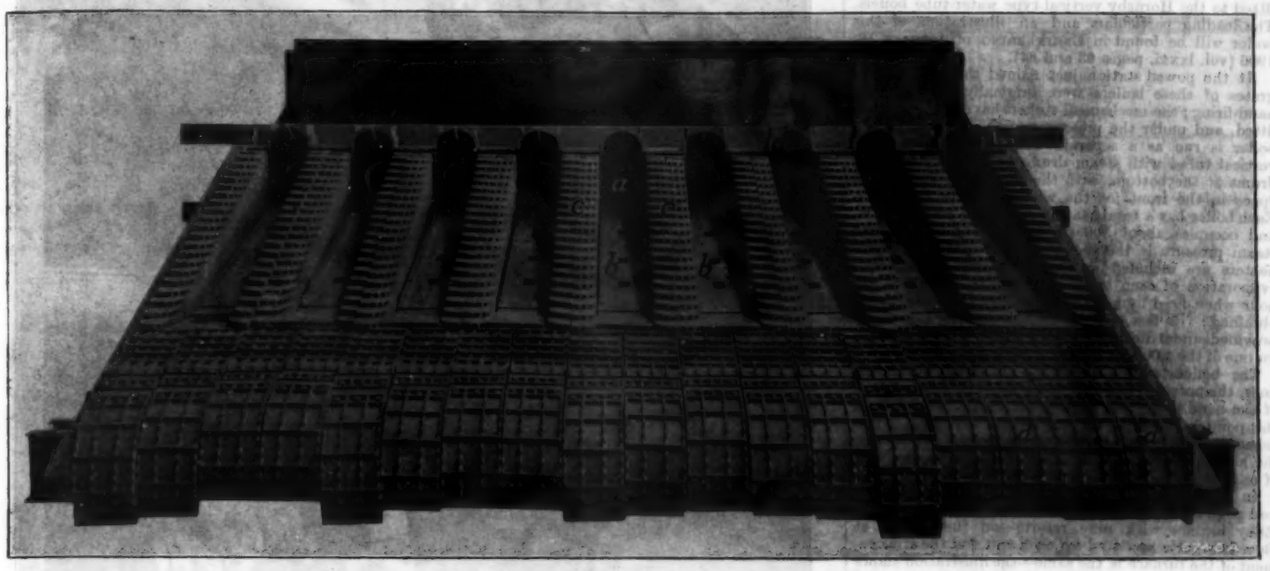
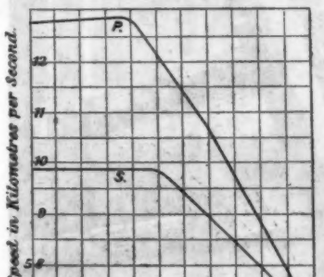


FIG. 1.

based on Hamilton's integral theory as mentioned, discarding all assumptions.

These calculations led to a modification of the figures previously arrived at. Plotting the velocity of the P and S as ordinate against the depth, *i.e.*, the distance of the wave, which had originated somewhere near the surface, from the Earth's centre, Professor Knott found that the velocity of both P and S increased as the wave front advanced deeper into the earth, and that both the velocities became nearly constant at a distance of about 5,000 km. from the centre of the Earth. The final constant velocity of P was 12·8 km., that of S 9·8 km.; but the slope of P was steeper than that of S, and the S wave bent over sooner than the P wave. In the annexed diagram the origin of the earthquake



is on the right, the centre of the Earth would be to the left on the abscissa, and the figures on the abscissa indicate distances from the Earth's centre in thousand kilometres. Both the elastic constants k and n might vary with increasing depth and density; if they varied at the same rate, the ratio V/v should be constant. But the ratio did not prove constant, and it hence appeared that the k and n did not vary according to the same law, the n being sooner (at smaller distance) affected than the k. The study of the paths of seismic rays through the Earth supported these conclusions. The paths, Professor Knott found, were curved for short arcual distance between the station and the epicentre, the convex side being turned to the diameter drawn from the epicentre. With greater distance the paths become more and more chordal; they were not really straight, however, not only because they bent over at both the ends, but they showed a slight change of curvature in the middle fairly straight portion.

Considerations of the distribution of the earthquake energy, Professor Knott continued, were also in accord with the main deduction drawn that the Earth's interior was not solid, but contained a fluid, or at any rate, non-rigid nucleus. That was an old suggestion of the geologists, renewed with special regard to Indian earthquakes by R. D. Oldham in the very early days of earthquake research. A fluid had no rigidity; the n term vanished, therefore, in the velocity formulæ. The energy argument was the following: If a seismic ray entered a medium of different density or elasticity, the ray would be refracted, that is to say, the velocity of propagation would be changed; there would further be reflection, and there might be total reflection as in the case of light, and the refraction and reflection would be different for compressional and distortional waves. Hence the energy of the wave leaving the second medium might appear concentrated or dispersed. Professor Knott elucidated these features with the aid of two figures which looked like optical diagrams. In each a sphere (or hemisphere) of non-rigid substance was surrounded by a shell of rigid material; optically the sphere corresponded to the lens, the shell to the outer medium. A bundle of compressional rays originating on the outside of the shell fell upon the sphere like a pencil of light rays; their total energy represented 100 per cent. In the first diagram the rays were compressional; 34 per cent. of the rays were reflected before entering the sphere, and 18 per cent. of these had been transformed into distortional rays; 66 per cent. entered being refracted downward as by a convex lens; of the rays leaving the sphere 50 per cent. were again bent downward being compressional, whilst the remaining 16 per cent. (distortional) were refracted upward. In the second diagram of the 100 per cent. of distortional rays falling upon the sphere, only 12 per cent. were able to enter, the rest being reflected backward; in the sphere the rays were refracted upward as in a concave lens, and only 8 per cent. were concentrated on the further side of the sphere.

Thus, the lecturer remarked in conclusion, the distortional waves would largely be dispersed and reflected back to the points near their origin, only a small portion of them reaching far distances across the globe. The conclusions seemed to bring us back to the old view that the Earth consisted of a non-rigid nucleus of about 0·4 the whole radius, confined within a rigid shell of a thickness equal to 0·6 of the radius. The phenomena were exceedingly complex; yet earthquake research alone seemed to enable us to investigate the interior of the Earth, and if it were not that other claims were made upon the resources of the country, he would plead for the installation of 20 Galitzin seismometers in different parts of the Empire.

THE COTTON WASTE TRADE.—The considerable extent of the development of the trade of working-up cotton waste in Germany is instanced by the figures of export of waste from this country to various destinations. The figures also point to the competition which firms in this country were experiencing in the home market from the German manufacturer. This competition was a serious one in spite of the distance of the German factories from the English markets. The following figures of the export of cotton waste from the United Kingdom, quoted in *The Board of Trade Journal*, speak for themselves:—

Destination.	1912. Lb.	1913. Lb.	1914. Lb.
Germany ...	31,282,000	35,994,000	18,472,000
France ...	12,721,000	13,978,800	7,642,000
Belgium ...	10,425,000	11,152,000	6,935,000
U.S.A. ...	8,558,000	10,327,000	6,133,000
Netherlands ...	5,886,000	7,520,000	5,450,000

The waste is made up into low-class materials, sponge cloths, twine, hosiery, blankets and cheap cloth. Extensive research work has been carried out in Germany in the past as to the best means of utilising this waste, and special machinery has been devised and constructed with this object in view. There is a similar and very important industry in France and Belgium, and as the above figures of export of cotton waste from the United Kingdom indicate, considerable exports of waste for this industry went from this country to France and Belgium. The growing hold of Germany on this trade was further exemplified before the war by the fact that in the export of waste to France and Belgium the German merchant was becoming the essential medium for its disposal. That the German industry is very much alive to the serious position engendered by the dislocation of its control of the raw material market by the war is indicated by reports which come to hand from time to time of the attention which the waste markets of the Far East have been receiving from German agents. No doubt the demand in Belgium and France will be very great in the reconstruction period, and it is desirable that efforts shall be made to eliminate the influence of the German merchant with a view to ensuring adequate supplies of raw material to our Allies. At the same time, it is to be hoped that the efforts that have been made to establish the industry here will be extended with the awakening that has taken place in research in connection with the cotton trade.

ERITH-RILEY MECHANICAL STOKERS.

The Erith-Riley stoker has been specially developed for working in conjunction with large boiler plants installed on the unit system, and one of the latest examples is the installation of large-unit stokers at the Bow Power Station of the Charing Cross, West End and City Electricity Supply Corporation, Limited, fitted to the Hornsby vertical-type water-tube boilers. The leading particulars and an illustration of this boiler will be found in Engineering of January 12, 1906 (vol. lxxxi, pages 63 and 64).

At the power station just named the settings and grates of these boilers were originally arranged for hand-firing; the mechanical stokers have only just been fitted, and under the present system of working each boiler is run as a separate unit. The boilers have vertical tubes with steam drums at the top and mud drums at the bottom, with the casing set back and a space in the front for the withdrawal of the tubes. Each boiler has a total heating surface of 10,850 sq. ft. and occupies about 506 sq. ft. of floor space. The steam pressure is 180 lb. per square inch and superheaters are included in the equipment. The rated evaporation of each boiler is 33,000 lb. of steam per hour when fired by hand, but higher duties have been obtained; in fact, a pair of the boilers has easily provided under normal working conditions the steam for one of the 4,000-kw. Sulzer-Lahmayer sets.

The boilers were installed in 1904 on up-to-date lines, the only additions required to take full advantage of the handling of the fuel by mechanical means from the point of delivery on site to the discharge of the ashes, being the fitting of the mechanical stokers and the horizontal distributing screw conveyor on the front of each boiler.

In the illustrations on page 267, the present page, and page 269, Fig. 1, page 267, is a view of the Erith-Riley furnace with nine retorts—on the boilers at Bow 12 retorts are fitted for each unit, but the arrangement of the furnace is the same—the illustration shows (*a*) the rams, (*b*) the retorts, (*c*) the tuyeres, and (*d*) the rocker plates for agitating, crushing and discharging the ashes.

The general views, Figs. 2 and 3, show the stoker-gear and the method employed for conveying the fuel from the down-shoot to the hoppers on the stokers. The screw coal conveyor and distributor is required in this case, as the front face of the boilers are at right angles to the centre line of the boiler-house.

Fig. 4 shows the boilers in elevation, and gives a clear idea of the space occupied by the units, the general lay-out of the stokers and the combustion chamber, it should be noted that there is no arch in the combustion chamber, which is an important matter when high-temperature combustion is being maintained, and that the firebrick lining on the face of the combustion chamber runs straight across and, due to its inclination, had to be fixed to the casings by special means.

Fig. 5 shows the front face of the boilers with the stoker gear in position with the motor for driving the shaft, the fan and the overhead track for the suspended ash truck into which the ashes are loaded direct from the ash pits.

From the illustrations it will be seen that each boiler is equipped with its own operating plant, which comprise an electrically-driven fan for the air supply to the furnace, a variable-speed motor for driving the stoker gears, and means for regulating by hand the amount of opening of the ash plate. These, with the necessary adjuncts on the stoker gears, are provided to secure, independent control of the unit and the economical working of the plant and, further, safety attachments are introduced to reduce the effect of breakages to a minimum.

The working of the apparatus is simple and easily controlled, the coal having been delivered into the coal hopper, is fed by the slow-running crankshaft from which the rams derive their forward and backward motions, into the retort units, the coal is pushed forward and rises upwards from the retort, spreads over the tuyeres through which the air necessary for combustion is delivered; it is coked, and the volatile hydrocarbons distilled in the low temperature fuel zone, the burning mass of fuel rises into the high-temperature zone of final combustion, so that the combustion is completed within the fuel bed itself, the thick fire-bed forming its own combustion arch; by these means the heat radiates direct upon the tubes of the boiler.

The crankshaft also reciprocates the tuyeres and the rocking ash-discharging plates, all the motions are in unison and continuous, and therefore the bed of fuel is being automatically fed forward from its entry in the retort to the discharge of the ashes into the ash pit.

We hope that it may be possible in a subsequent issue to give some details of the results obtained through the introduction of the stokers on these large boilers.

The stokers were installed by the Erith Engineering Co., Ltd., of 70, Gracechurch-street, E.C. 3.

THE ERITH-RILEY MECHANICAL STOKER.

CONSTRUCTED BY THE ERITH ENGINEERING COMPANY, LIMITED, LONDON.

Fig. 2.

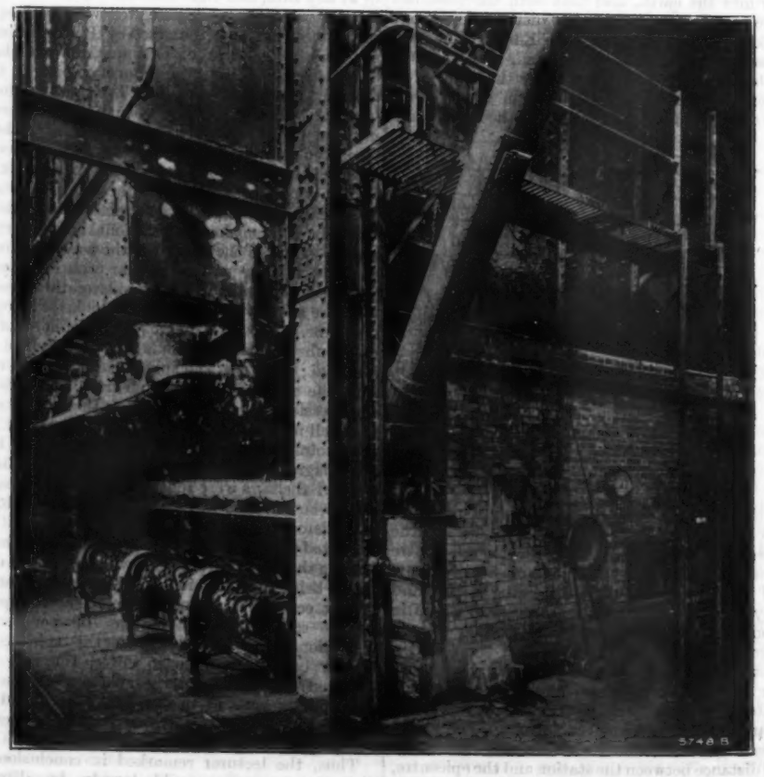


Fig. 3.

THE ERITH-RILEY MECHANICAL STOKER.

CONSTRUCTED BY THE ERITH ENGINEERING COMPANY, LIMITED, LONDON.

(*For Description, see opposite Page.*)

Fig. 4.

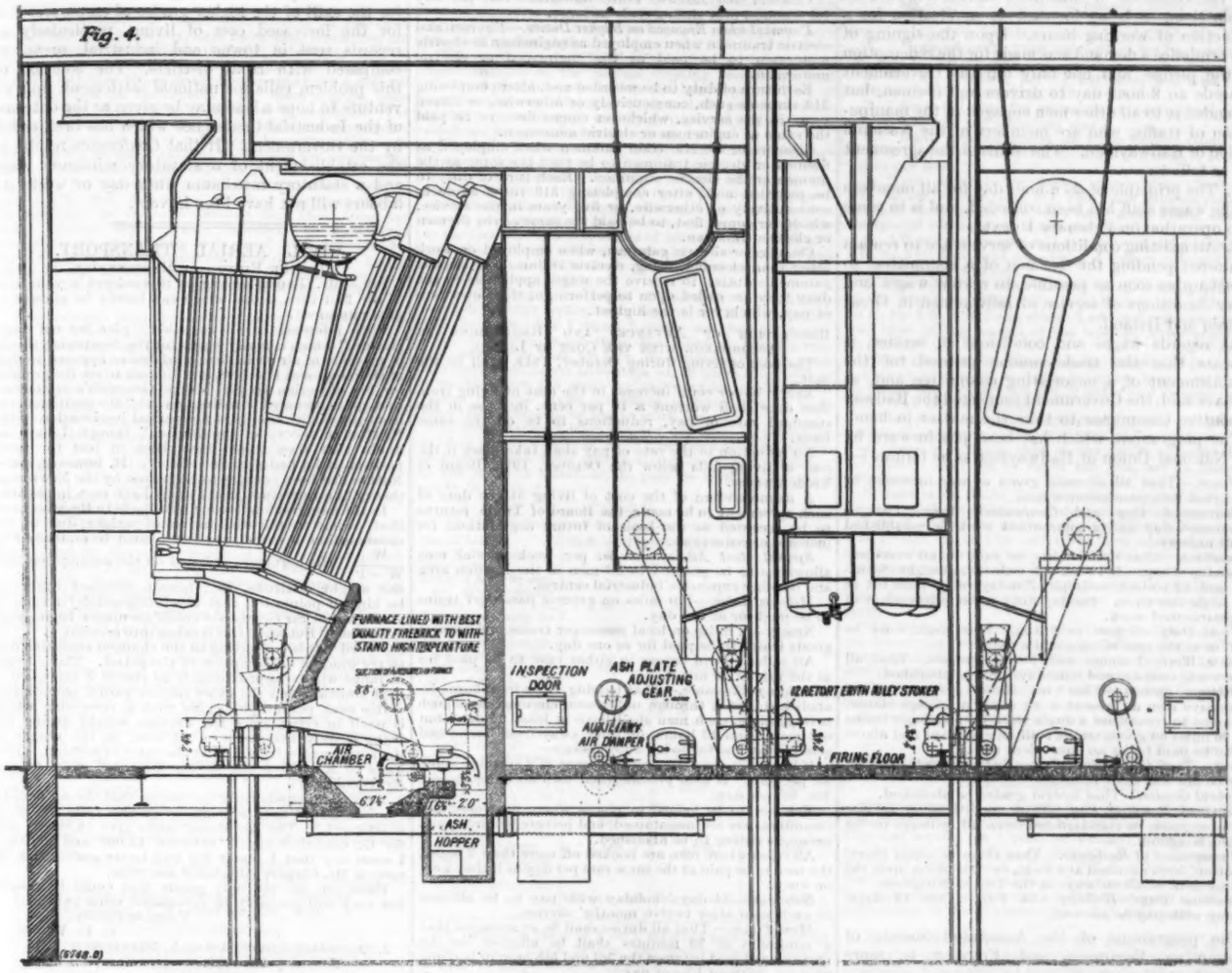
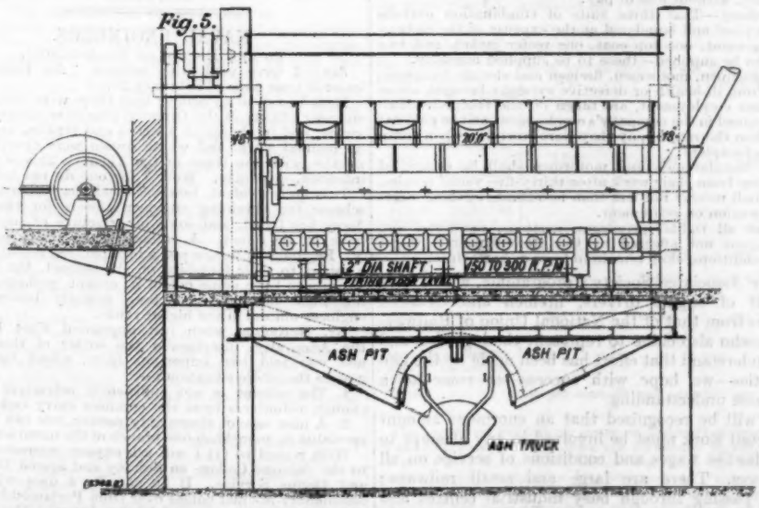


Fig. 5.



RAILWAY LABOUR CONDITIONS.

THE Railway Executive Committee are now engaged in negotiating with the National Union of Railwaymen and the Associated Society of Locomotive Engineers and Firemen in respect of programmes of demands, which, if conceded, even to a small extent, will have the effect of very materially increasing the already inflated cost of operation of the railways of the country. From time to time we have given in these columns information as to the various concessions which have been made to railway employees during the war. The grades concerned in the manipulation of traffic have been granted war wages which now amount to 33*s.* a week in the case of male employees of 18 years of age and over, and half that sum to boys under that age. These war wages were given under the terms of a Truce Agreement whereby pre-war conditions of service remained unaltered during the war. That agreement has been terminated by the trade unions, and the problem now is to establish permanent conditions of service. In normal circumstances it would have fallen to the various railway Conciliation Boards to agree what those conditions should be, and in this connection we may point out that, whatever may be said as to the adequacy or otherwise of pre-war rates of wages, it has to be remembered that in every case they were fixed by agreement between the railway companies and representatives of the men. In other words, no single rate of wage was arbitrarily fixed by a railway company—indeed, during the decade commencing with the establishment of the Conciliation Scheme in November, 1907, the wages, hours and conditions of service of railwaymen were the subject of arbitration or agreement on more than one occasion. Now that railway companies are temporarily under Government control the negotiations are conducted by the Railway Executive Committee on behalf of all companies, and the present negotiations are the direct outcome of an agreement which was entered into by the Board of Trade with the National Union of Railwaymen and the Associated Society of Locomotive

Engineers and Firemen on December 6 last. Without reviewing in detail the circumstances preceding that agreement, we may say briefly that a pledge had been given by the Government to the Associated Society of Locomotive Engineers and Firemen that on the cessation of hostilities facilities would be given them to bring forward an application for a reduction of working hours. Upon the signing of the armistice a demand was made for the redemption of the pledge, and not only did the Government concede an 8-hour day to drivers and firemen, but extended it to all other men engaged in the manipulation of traffic, who are members of the National Union of Railwaymen. The terms of the agreement are as follow :—

1. The principle of an 8-hour day for all members of the wages staff has been conceded, and is to come into operation on February 1 next.

2. All existing conditions of service are to remain unaltered pending the decision of a committee, to be set up as soon as possible, to review wages and other conditions of service of railwaymen in Great Britain and Ireland.

As regards wages and conditions of service, it appears that the trade unions pressed for the establishment of a negotiating committee and, as we have said, the Government requested the Railway Executive Committee to take the matter in hand.

The programme which has been put forward by the National Union of Railwaymen is as follows :—

Wages.—That all advance given as war increases be converted into permanent wages.

Guaranteed Day and Guaranteed Week.—That a guaranteed day and a guaranteed week be established on all railways.

Overtime.—That double time be paid for all overtime.

Sunday Duty.—Between 12 o'clock midnight Saturday and 12 o'clock midnight Sunday to be paid for at rate of double time. Sunday duty to be independent of the guaranteed week.

Night Duty.—6 p.m. to 6 a.m. That night duty be paid for at the rate of time and a half.

Piece Work, Tonnage and Bonus Systems.—That all piece work, tonnage and bonus systems be abolished.

Mileage System.—That on those systems where locomotive men at present work under a mileage clause, 120 miles to constitute a day's work on passenger trains and 96 miles on goods trains ; all mileage over and above this to be paid for at an equivalent rate.

Rest.—That the period of rest between each turn of duty be not less than 12 hours.

Hybrid Grades.—That hydrid grades be abolished.

Standard Rates of Pay.—That conditions of service for railwaymen be standardised upon all railways in the United Kingdom.

Management of Railways.—That there be equal representation, both national and local, for this union upon the management of all railways in the United Kingdom.

Fourteen Days' Holiday with Pay.—That 14 days' holidpy with pay be allowed.

The programme of the Associated Society of Locomotive Engineers and Firemen is more elaborate, viz. :—

Eight-Hours' Day—Interpretation.—That no man shall be diagrammed to work more than 8 hours for any one booking—this 8 hours to be inclusive of all allowances from the time of "booking on" to "booking off" duty at the locomotive or electric shed, subject to the proviso that when extraordinary circumstances arise, such as delays by bad weather, breakdowns, or traffic delays, the company must have the men relieved before or on completion of the 8 hours from the time of booking on duty. The men relieved to then travel to their home station.

All time occupied over the 8 hours on this or any other occasion that may arise shall be paid at the rate of time and a half.

Sunday duty to be paid for as double time from Saturday midnight to Sunday midnight, this also to apply to Good Friday and Christmas Day.

Time and a half for all overtime and for night duty between 6 p.m. and 6 a.m.

Guaranteed day for each time of signing on duty. Each day to stand by itself.

Guaranteed week exclusive of all time worked between 12 midnight Saturday to 12 midnight Sunday. Each week to stand by itself.

That special duties be eliminated, but if such is impossible, then the following procedure shall apply. Men not booked for regular trains or bookings and not required for duty between the 12th and 16th hour from booking off duty, shall be paid one day's pay. They shall then not be called upon for duty until they have had a further 9 hours off duty.

Rest.—At least 12 hours' rest between each turn of duty at home station. At least 9 hours' rest when booked off away from home.

WAGES.

Enginemen and Electric Motormen.—20*s.* per day (of 8 hours) plus sliding scale increase. Enginemen or electric motormen reduced to firemen or electric trainmen to suffer no reduction in the above scale.

Firemen and Electric Trainmen.—15*s.* per day (of 8 hours) plus sliding scale increase.

Any man working as a fireman or electric trainman who has been in the service for fifteen years and not promoted to engineman or electric motorman, to be paid the engineman's or electric motorman's scale.

Firemen or electric trainmen reduced to cleaners or electric train gatemen to suffer no reduction in the above scale.

Cleaners and Electric Train Gatemen.—10*s.* per day (of 8 hours) plus sliding scale increase.

Payment when Engaged on Higher Duties.—Firemen and electric trainmen when employed as enginemen or electric motormen to be paid as the enginemen or electric motormen.

Each turn of duty to be recorded and, after completing 313 turns as such, consecutively or otherwise, or fifteen years in the service, whichever comes first, to be paid the same as enginemen or electric motormen.

Cleaners or electric train gatemen when employed as firemen or electric trainmen to be paid the same as the firemen or the electric trainmen. Each turn of duty to be recorded and, after completing 313 turns as such, consecutively or otherwise, or five years in the service, whichever comes first, to be paid the same as the firemen or electric trainmen.

Cleaners or electric gatemen, when employed on work other than cleaning, firing, electric trainmen or electric gatemen's duties, to receive the wages applicable to the duty they are called upon to perform, or their own rate of pay, whichever is the highest.

REGULATION OF ADVANCES AND REDUCTIONS IN ACCORDANCE WITH THE COST OF LIVING.

The cost of living during October, 1918, shall be the unit.

Every 10 per cent. increase in the cost of living from that date shall warrant a 10 per cent. increase in the standard rate of pay, reductions to be on the same basis.

No reduction in the rate of pay shall take place if the cost of living falls below the October, 1918, Board of Trade returns.

A memorandum of the cost of living at the date of such agreement to be made, the Board of Trade returns to be accepted as the basis of future negotiations for increase or reductions.

Special Rent Allowance.—5*s.* per week special rent allowance to be granted to all men in the London area and in other expensive industrial centres.

Mileage Rates.—120 miles on express passenger trains to be paid for as one day.

Ninety-six miles on local passenger trains and express goods trains to be paid for as one day.

All miles run in excess in either case to be paid for at the rate of 10 m.p.h.

Lodging Allowance.—That lodging away from home be abolished, but if through unforeseen circumstances such is impossible, each man shall have at least 9 hours, but not more than 12 hours, off duty away from home, and also receive the following allowances :—

If lodged at the company's expense at a suitable hotel, 4*s.* per day. If men provide their own accommodation, 10*s.* 6*d.* per day.

Men not to be lodged in places where quietness and cleanliness are not maintained, and private lodgings as at present existing to be abolished.

All cases where men are booked off more than 9 hours, the men to be paid at the same rate per day as if they were on duty.

Holidays.—14 days' holiday with pay to be allowed to each man after twelve months' service.

Meal Times.—That all duties shall be so arranged that a minimum of 30 minutes shall be allowed for the partaking of food between the 3rd and 5th hour of booking on duty, without loss of pay.

Clothing.—That three suits of combination overalls be supplied and laundered at the expense of the railway management, one top coat, one reefer jacket, and two caps to be supplied—these to be supplied annually.

Enginemen, motormen, firemen and electric trainmen, who from ill-health or defective eyesight brought about by their employment, are taken off the footplate, shall be retained in the company's employment and be paid not less than the rate of pay they were receiving when taken off the footplate.

All footplatemen and motormen shall be compelled to retire from their work after thirty-five years' service, and shall receive not less than two-thirds of their wages as a pension on retirement.

That all rights, privileges, customs, practices, and conditions not affected by the aforementioned wages and conditions, shall remain in force as heretofore.

The Associated Society's programme, which is on behalf of engine drivers, firemen and cleaners, differs from that of the National Union of Railwaymen, who also claim to represent these grades, and we understand that effort has been made by the two societies—we hope with success—to come to a common understanding.

It will be recognised that an enormous amount of detail work must be involved in any attempt to standardise wages and conditions of service on all railways. There are large and small railways ; lines passing through busy industrial centres and rural districts, and in our opinion to adopt a flat rate, applicable alike in town and country, would cause more unrest than it would remove. As a matter of fact the railways are suffering under the same disability as engineering employers ; the flat rate war wages of 33*s.* a week, which corresponds to the craftsman's 28*s.* 6*d.*, plus 12½ per cent., has disturbed the relationship between the different grades, and until some authoritative lead is given by the Government as to what the minimum rate of wages for ordinary labourers should be, it is difficult, if not impossible, satisfactorily to erect a structure of permanent wages with due allowance for the skill of the higher grades of employees and for the increased cost of living, particularly as regards rent in towns and industrial areas, as compared with rural districts. The solution of this problem calls for national settlement, and we venture to hope a lead may be given as the outcome of the Industrial Conference which has been called by the Government. If that Conference results in the establishment of a statutory minimum wage and a statutory maximum work day or week, its labours will not have been in vain.

CIVIL AERIAL TRANSPORT.

TO THE EDITOR OF ENGINEERING.

SIR,—Mr. Glauert's letter on this subject in your issue of the 21st inst. is one which can hardly be allowed to pass unnoticed.

With reference to his so-called "plea for old dame Nature," which is really a plea for the Newtonian theory of pressure of air on inclined surfaces as opposed to that of Helmholz and Kirchoff, it is difficult to see the grounds for his objection to Sir George Greenhill's statement. I am quite prepared to maintain that "the position of the heavenly bodies to-day is a practical justification of the Newtonian theory of gravitation," though I have no doubt that they would have been in just the same position if he had died in infancy. If, however, dame Nature had been content to be guided by the Newtonian theory of air pressure, flight *would* have been impossible.

In the paragraph following he objects to the statement that owing to the diminution of weight, due to the consumption of petrol, the range must be multiplied by $\frac{W}{W-P}$. His argument is based on the assumption that the weight, attitude, &c., remain constant (although he himself points out that this is impossible) in spite of the fact that Sir George Greenhill's sentence begins with the words "But when this is taken into account . . ." the word "this" referring to the changed condition due to the gradual consumption of the petrol. The increase in range will be approximately as stated if the speed is kept constant and the other factors varied accordingly.

His next paragraph begins with a correction which is itself in error, since the average weight during the flight is only five-sixths of 6½ tons, as the weight of the petrol varies from ½ W at the start to nothing. This leads to K = 83·6 (Sir George Greenhill gives 84 and Mr. Glauert 91).

Your correspondent further states that the air density "is not halved until a height of greater than 20,000 ft. is attained." The Air Board tables give 18,800 ft. and Sir G. Greenhill says "between 15,000 and 20,000." I must say that I prefer the two latter authorities, in spite of Mr. Glauert's dogmatic assertion.

These are not the only points that could be raised, but they will probably be considered quite sufficient.

Yours faithfully,

C. E. WOLFF.

2, Devonshire-street, Ardwick, Manchester,
February 23, 1919.

NAVAL ENGINEERS.

TO THE EDITOR OF ENGINEERING.

SIR,—I have read with interest "An Engineer's" letter in your issue of February 21.

Does he ask us to believe that there were thirty-three engineer officers in the Olympic who were simply supervising, and in charge of watches and repairs, and doing no manual work, and whose duties were exactly comparable with the three in the Tiger. This is what is intended, evidently. Well, I for one do not believe it.

It is quite evident, however, that the Selborne-Fisher scheme for obtaining engineer officers for the Royal Navy has failed, and some other source of supply will have to be found. A committee of three, of which Mr. Reginald McKenna was a member, has recently made a report to their lordships on the subject, but nothing appears to have come out of it, except, perhaps, that a few more honours have been recently bestowed on engineer officers in the higher ranks.

Mr. McKenna, when just appointed First Lord of the Admiralty, interviewed the writer of this letter, and was told two important facts, which facts still govern the whole situation :—

1. The scheme is not sufficiently attractive to get enough volunteers from the common entry cadets.

2. A man cannot thoroughly master, nor can he be a specialist in, more than one branch of the naval service.

With regard to (1) I will ask anyone interested to go to the Osborne College on Sunday and attend Divisions and Divine Service. If he can fix a date when the commander-in-chief comes over from Portsmouth for his official inspection, so much the better. The visitor interested will find all the executive officers—the captain, the commander, and the term lieutenants—covered in decorations, and all very much in the limelight ; and he will, if he sees any engineer officers at all—which is doubtful—find these officers very much in the background, minus decorations, and taking no part whatever in the ceremonies.

What does the young cadet think ? What can he

think? He naturally says to himself, "the engineer officer is a passenger and is of no account or importance." The impression the young cadet gets at this stage will remain in his mind during the whole of the time he is in the service. Is this boy likely to volunteer for the engineering branch of the service unless there are very great compensating advantages? He is certainly not likely to.

I am constantly in touch with officers in the fleet, and I am told definitely, and have also found out for myself when I was afloat, that the Admiralty are not playing the game with the lieutenants "E," and that, if it is a fact that the engineer-lieutenants have a difficult position, then the lieutenants "E" have a much more difficult one. I could give instances if required. The fact remains, however, that the attractions are absent.

With regard to (2), if sufficient attractions did exist, there would be quite enough volunteers for engineering duties; the officers selected would, and must, remain engineers for the whole period of their service careers. These will, and do, make excellent engineer officers. In fact, they are far more efficient than those from any other source. They must, however, be considered specialists in engineering only, and look forward to, and be given, certain important positions in the higher ranks of the service, which must be looked upon as billets only to be filled by officers who are engineering specialists.

I understand that it has been recently decided that the "E" officers are not now to be eligible for Admiral Superintendents of Dockyards. Well, all I can say is, that unless plums of this sort are held out, volunteers will not be forthcoming. Only by giving "E" officers an extremely high rate of pay, and promises of good appointments after reaching a certain rank, can we hope to get the numbers we require. Of the quality there can be no doubt.

I am, Sir, yours faithfully,

February 25, 1919. "A NAVAL ENGINEER."

FATE OF THE GERMAN FLEET.

TO THE EDITOR OF ENGINEERING.

SIR,—In view of the erstwhile professions of friendship for Ireland by Germany, would it not be appropriate to utilise some of the ships of the High Seas Fleet in the construction of the proposed national commercial and naval harbour in Galway Bay?

As engineers of the scheme for the harbour at Barna, near the head of the bay, we are satisfied that by the use of say, six or eight of the larger ships, and some of the smaller ones, a very considerable saving would be effected in the cost of construction of the harbour. The ships could either be sunk in deep water in such a manner as to shelter the site of the harbour, and so facilitate the construction of the breakwaters, or they could be sunk on the actual lines of the breakwaters and incorporated in them.

There are, of course, many other harbours in the British Isles and the Dominions where the ships could do equally valuable service, but seeing the expense to which this country has been put by the attempts of the Germans to stir up unrest in Ireland, it will surely be conceded that the harbours in our islands should have the first call.

We are, Sir, yours faithfully,

BAKER AND HUBTZIG.

2, Queen Square-place, Queen Anne's Mansions, Westminster, S.W., February 26, 1919.

THE LJUNGSTROM TURBO-ELECTRIC SYSTEM.

TO THE EDITOR OF ENGINEERING.

SIR,—In following a discussion published in an Italian review I have had the opportunity to peruse the article, "The Ljungstrom Turbo-Electric System of Ship Propulsion," which appeared in ENGINEERING of August 9, of last year, page 140, where curves of efficiency and power of induction motors are given. As no special mention there is made of the speed of induction motors at which the various power are developed, I suppose that the curves are relative to trials made as usual with a variation of the resisting couple and with a rotor speed corresponding to equilibrium, but differing little from synchronism (720 r.p.m.).

Now, as the rotor is coupled to a ship's screw, its speed must be the corresponding one to the power transmitted, say to satisfy the cubic law, so that a large variation of the rotor speed must occur. Then, as frequence of current is kept constant with turbine speed constant, the slip of rotor must increase somewhat rapidly as power decreases, and efficiency decrease more rapidly than shown by the curves.

May I now say, that being so, the curves may be misinterpreted as they show an efficiency not corresponding to real working of motors with screw coupled?

If you publish this in order to have this point cleared by those responsible for the said article, I will be thankful to you.

Yours faithfully,

RINALDO ZUNINO,

Tenente del Genio Navale—Royal Italian Navy, Via Cuneo 20—Torino (Italy).

Torino, January 21, 1919.

[Our correspondent is quite correct. It is not practicable to carry out detailed tests of the motors when driving the propeller at reduced speed. Indeed, such tests being made with variable frequency and external resistance, would not give the characteristics of the motor, but those of the equipment. It therefore appeared to us to be preferable to publish the usual curve for the motors with normal frequency and voltage applied to the stator circuits, and with the rotor short-circuited; the speed being near to synchronism at all speeds.—ED. E.]

"COAL SAVING AND SCIENTIFIC CONTROL OF STEAM BOILER PLANT."

TO THE EDITOR OF ENGINEERING.

SIR,—Mr. Brownlie in his report of the tests of 1,000 steam boilers gave us in a concrete form facts relative to the coal wastage going on around us daily, and the letters which have appeared since July last on the above subject give some indication of how much the report has been appreciated.

The results secured by Mr. Brownlie may be taken as representative of the general existing conditions, and if so, we pass into our boilers the heat from 57 tons of coal out of every 100 tons stoked, and the principle cause of this huge wastage is merely giving to the furnaces too much air per pound of coal burned.

That too much excess air is the cause of coal wastage is proved by the above-mentioned report, as 2 per cent. of the 1,000 boilers when fed with coal and air in the proportion of 1 to 18 indicated by 13 per cent. CO_2 gave over 80 per cent. efficiency, whereas 17 per cent. of the boilers gave less than 50 per cent. efficiency, solely due to the fact that the proportion of air and coal was 33 to 1 and the average efficiency of the 1,000 boilers was 57 per cent., or 30 lb. of air per pound of coal indicated by 7·6 per cent. of CO_2.

Mr. Dunlop, in his letter of Saturday week, kindly reminds us that boilers have been in use in this country 200 years, &c., but I regret I cannot see that our knowledge of how to work them has followed Topsy's rule and growed, or that his own observations twenty years ago have been taken advantage of, as there is no part of a works where the same ignorance exists as the boiler house, but the boiler attendant is much less at fault than the conditions he has to work under.

In other letters I have pointed out how, by providing in tank boilers a ratio of 25 to 1 between heating surface and grate area both the steaming duty and efficiency of the boiler is sacrificed, as may be seen by a careful study of Table A:—

TABLE A.

Size of boilers	30 ft. by 7 ft.	30 ft. by 8 ft.	30 ft. by 9 ft.
Length of grates	6 ft.	6 ft.	6 ft.
Grate areas	33	38	45
Ratio of grate to outlet from furnace flues	4 to 1	3·5 to 1	2·75 to 1
Chimney draught in feet per minute	1,500	1,500	1,500
Air velocity through fire grates, in feet per minute	375	427	550
Coal burned, in pounds per square foot of grate per hour	14	17	21
Furnace temperature, approximately	1,800 deg.	1,800 deg.	1,800 deg.
Water evaporated per pound of coal (approximate)	6¾ lb.	6¾ lb.	6¾ lb.
Evaporation in pounds per square foot of grate	94	114	142
Evaporation in pounds per hour	3,168	4,320	6,486
Excess air percentage theoretical weight required per pound of coal	150 per cent.	150 per cent.	150 per cent.

By making a ratio of 2 to 1 between grate and outlet in all sizes of tank boilers, the proportion of heating surface to grate area is increased, and results secured are approximately indicated on Table B:—

TABLE B.

Size of boilers	30 ft. by 7 ft.	30 ft. by 8 ft.	30 ft. by 9 ft
Length of grates	3 ft.	3 ft. 9 in.	4 ft. 9 in.
Grate area, square feet	17	25	35
Ratio of grate to outlet	2	2	2
Chimney draught, in feet	1,500	1,500	1,500
Air velocity through fires	750	750	750
Coal burned per square foot of grate per hour	41	41	41
Approximate furnace temperature	2,700 deg.	2,700 deg.	2,700 deg.
Evaporation per pound of coal	8·4 lb.	8·4 lb.	8·4 lb.
Evaporation per square foot of grate	344 lb.	344 lb.	344 lb.
Evaporation in pounds per hour	5,848 lb.	8,600 lb.	12,040 lb.
Excess air percentage over theoretical weight per pound of coal	50 per cent.	50 per cent.	50 per cent.

The improved conditions given on Table B are secured by automatically cutting down the air supply by reducing the grate area and working with thicker fires and thereby securing a higher furnace temperature, and this is not interfering with, but taking more advantage of, natural laws than has been done in the past, and this is all your various correspondents and Mr. Brownlie has attempted; where, then, does your correspondent find indication of the superman who attempts to wrest secrets from Nature, &c., &c.

With fuel at 20s. per ton, a steam boiler working on the lines given on Table A (the present general conditions) will cost 13s. 3d. to evaporate 1,000 gallons of water, but the same boiler worked under Table B will evaporate 1,000 gallons for 9s. 9d., and this means, with a modern engine 600 h.p., a saving of nearly 10l. per week, and principally by giving 50 per cent. excess air over the theoretical weight required per pound of coal, as against 150 per cent. formed by Mr. Brownlie in his big test already mentioned.

That reducing grate area and minimising the supply of excess air is not a "bee-in-the bonnet theory" may be gathered from the following extracts from clients who are working their boilers on the lines of Table B:—

1. "Since adopting your suggestions we have reduced our fuel bill 10 per cent."

2. We are working for 7½ per cent. less coal since reducing boiler grates from 6 ft. to 4 ft.

3. "Since reducing fire grates we are saving coal at the rate of 140 tons per boiler per year."

4. "Have reduced grates on three boilers from 6 ft. to 4 ft.; coal saved on six months' working, 1 ton per boiler per week."

5. "We reduced our boiler grates (four 30-ft. by 8-ft. boilers) from 6 ft. to 3 ft. 10in., and adopted induced draught three years ago, and have since saved coal at the rate of 150 tons per boiler per year."

6. "In our own works we have reduced the grates from 6 ft. to 3 ft. 3 in., and are saving 2 tons of coal per week on three years' working."

7. The following is an extract from a letter received on the 20th inst., from a firm who have in use 13 boilers, 30 ft. by 8 ft. 6 in., and where I advised reduced grates, &c., after giving results of the test the letter concludes as follows:—

"The above tests show that the shortened grates are a distinct advantage, and this is further borne out by the fact that the fires are always brighter and cleaner in the short than the long grates.

"The short fires are sufficiently thick to prevent excess of cold air passing through, whilst with the long fires cases of burning thin at the back, allowing large volumes of cold air to reach the flue, are of frequent occurrence.

"There is no doubt that the shortening of the grates has increased the efficiency of the boilers very materially."

I could add to the above list over 200 cases where the 2 to 1 ratio of grate to outlet has been adopted, and the saving effected as a rule equals 100 tons of coal per boiler per year, and surely such are the results the world is asking for to-day and are positive indications the lines followed in scientific control of steam plant are correct.

The mistake made since the steam boiler came into existence has been too much preaching and too little practice, each generation following in the tracks of its predecessors, adopting without question the same wrong methods, until extravagance to-day tries to pose as economy.

Apologising for writing at such length,

I am, yours faithfully,

W. H. CASMEY.

Milnthorpe, Wakefield, February 24, 1919.

METROLOGY.—It is proposed to hold a discussion on "Metrology in the Industries" at the meeting of the Physical Society at 5 p.m. on Friday, March 28, 1919, at the Imperial College of Science, South Kensington. Sir R. T. Glazebrook, C.B., F.R.S., Director of the National Physical Laboratory, has consented to introduce the discussion, and it is expected that many of the leading authorities on fine measurements will take part.

COAL IN NEWFOUNDLAND.—We read in *The Marine Journal*, New York, that reports of geologists who have examined a coal deposit recently discovered on the West Coast of Newfoundland, indicate that enough coal is available to warrant mining operations. The coal seam which was found near the town of Godroy is believed by experts to be an extension of the deposits on Cape Breton Island, which produce millions of tons annually. If is stated that within eighteen months it will probably be possible to produce the total of 200,000 tons of soft coal used annually in this colony, which is now imported from Nova Scotia. Investigation of reported iron ore deposits on the island is also being made.

RUBBER VULCANISATION WITHOUT SULPHUR.—Some years ago a series of papers by I. Ostromyolenski appeared in the *Journal* of the Rusian Physico-Chemical Society on vulcanisation without sulphur by means of organic compounds resembling sulphur at melting point, vapour tension at vulcanisation temperature, solubility in rubber and other properties. He first tried trinitrobenzene, and afterwards the dinitro and nitro compounds of benzene, picric acid, peroxides and other compounds, and he came to the conclusion that the vulcanising agent must be able to promote polymerisation and to oxidise ethylene derivatives. Chemically his researches were very interesting; he was very indefinite as to mechanical tests of his vulcanised rubbers, however. Repeating many of his experiments and testing also the mechanical properties of the products, H. P. Stevens (*Journal of the Society of Chemical Industry*, 1917, page 107) did not arrive at any really satisfactory results. The investigation was recently taken up again in the Netherlands rubber-testing station at Delft by E. Bunschoten (*Kolloid Zeitschrift*, July, 1918), who, like Stevens, failed to obtain a lasting satisfactory vulcanisation. He experimented with the compounds recommended by Titromyslenski, adding the various organic and inorganic accelerators. A certain success was realised with lead oxides and some other cases, but the vulcanised rubber always lost its strength again within a few weeks. Bunschoten also questions the importance of oxidation. The oxidising agents which he tried, arsenic acid, potassium, permanganate and chlorate, sodium nitrate, &c., did not affect the rubber in the way he intended.

ANNEALING AND HEATING FURNACES FIRED BY TOWN GAS.

On page 276 is shown one of the latest developments in annealing and heating furnaces for firing by gas from the town main; it is the outcome of a thorough research carried out by the Technical Section of the Davis Furnace Company at their works in Luton, Beds. The furnace is worked on a new system which the firm have registered under the name of "Revergen."

The principle upon which the furnace is designed is shown diagrammatically in Figs. 1 and 2, annexed. The leading feature, and one by which the economies in consumption of town gas are achieved and from which the high temperatures are obtained, is the incorporation of regenerators for heating the air supply before it enters the furnace by means of the waste gases from the furnace. The Company have given considerable attention to the details of construction of the furnace in order that the thermal energy generally lost in the flue gases may be reduced by the transfer of this waste heat to the regenerators, and may in turn heat up the air supply through which it is made to pass before its entry into the furnace. The control of the gas supply and the air supply and reversal is so arranged that these operations may be easily and safely carried out.

The application of the system to a furnace is shown in Figs. 3 to 8, on page 276, from which it will be seen that the arrangement is compact. The two regenerators are built in the base of the furnace directly under the muffle. They run fore and aft with an external air manual with four ports on either side of the furnace. The usual system of heating the regenerator alternatively by the waste gases and abstracting the heat from it, is effected by means of the three-way air reversing valve shown in Figs. 3, 5 and 8, on page 276. The gas supply is opened to one side and cut off from the other side of the furnace by means of the one control lever shown in Fig. 3. This linking together of the gas supply valves and the air reversal valve makes it impossible for the operator to make mistakes, provided he pushes the handle right over to the stops.

There are no valves between the air reversing valve and the regenerators, but each inlet pipe to the gas burner is provided with an independent cock to allow adjustments to be made in order that there may be obtained a uniform temperature throughout the muffle. The cold air enters at the bottom of, for instance, the right hand regenerators; it is heated as it passes up the checker brickwork and out at the top, where it mixes with the gas and passes on into the furnace, producing a long and high temperature flame. The waste gases from the furnace then pass into and through the left hand regenerator, giving up their heat to the brickwork, and finally pass out through the bottom openings to the manual on their way to the flue outlet. During this period the gas supply is cut off from the burners on the left hand side of the furnace; on the reversal the cold air enters on the left hand and the waste gases pass away through the air manual on the right hand side.

The air is supplied to the furnace at a small pressure, say 2 in. to 3 in. of water, but the gas is taken direct from the gas main.

The furnace is built of firebrick and very few specials are used in the construction; the whole is encased in a wrought-iron casing and is well stayed by means of thrust plates and buck stays with tie bolts. A good point in the design is that the whole of the furnace, with the regenerators, is above workshop floor level. The furnace door is balanced and provided with a clamping device. In Fig. 4 the furnace is shown with one door, but there is no reason why a door should not be fitted at both ends of the muffle if required for the operation to be carried out in the furnace.

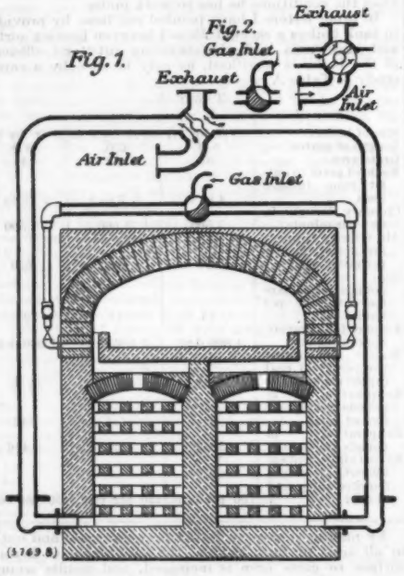
The Company recently arranged for a series of demonstrations to be carried out upon a furnace installed on the "Revergen" principle in the demonstration room at their Luton works. The tests were conducted on an oven furnace, the size of muffle being 32 in. by 54 in. by 24 in., and extended over a period of three days. The gas supply was taken from the town main and the air was supplied under pressure by a small fan driven by an electric motor.

The furnace was used on the first day for annealing, the object being to ascertain the gas consumption when annealing steel billets at 820 deg. C. The particulars were as follow:—

Size of billet	3½ in. in diameter × 21 in. long
Number of billets	20
Total weight charged... ...	987 lb.

On arrival the furnace was practically ready for the run, the temperature inside and at the back end of the muffle being 850 deg. C. The billets were placed in at 11.3 a.m., at 12.18 p.m. the desired temperature was reached; the gas consumption during the interval of 1 hour 15 minutes being 1,350 cub. ft., and therefore the gas used to heat up the charge was 1·37 cub. ft. per lb. of metal, or 3,064 cub. ft. per ton of metal, and the rate of heating was 790 lb. per hour. The temperature of the waste gases did not, during this portion of the trial, exceed 205 deg. F. (96 deg. C.), the thermometer being placed in the air manual between the second and third outlets.

After the gas had been reduced and the conditions



for the annealing at 820 deg. C. established, the test to ascertain the gas consumption to maintain the charged muffle at this temperature was continued for three hours. The readings were:—

For 1st hour, 300 cub. ft. = 0·304 cub. ft. per lb. per hour.
For 2nd hour, 250 cub. ft. = 0·253 cub. ft. per lb. per hour.
For 3rd hour, 325 cub. ft. = 0·328 cub. ft. per lb. per hour.

This gives an average over the three hours of 292 cub. ft. of gas per hour or 0·294 cub. ft. per lb. per hour.

The temperature of the waste gases during this section of the run were about 120 deg. F. (49 deg. C.). The average calorific value of the town gas during the day was 444 British thermal units per cubic foot. The reversal of the air supply was made at intervals of about 30 minutes. The heat was found, on the door of the furnace being opened on the completion of the trial, to be very uniform, and there was practically no scale on the billets.

The firm give the following additional information from particulars which they had received from the Ministry of Munitions of a test carried out on another type of furnace when working on a similar annealing operation:—

Gas consumption for heating up, 2·5 cub. ft. per lb.
Gas consumption for maintenance of a temperature of 825 deg. C., 1st hour, 0·534 cub. ft. per lb. per hour.

from which they have deduced the following comparison:—

	"Revergen."	Economy.
Gas consumption per ton heating up to 825 deg. C. ...	5,600	3,064	45 per cent.
Gas consumption per ton for 1st hour of maintenance ...	1,196	681	43 ,,

On the second day the same furnace was used for billet heating up to 1,000 deg. C., for which the following results were given:—

—	1st Charge.	2nd Charge.	3rd Charge.
Weight of billets ..	985 lb.	980 lb.	987 lb.
Number of billets ..	20	20	20
Time into furnace ..	11.09 a.m.	12.35 p.m.	2.05 p.m.
Time out of furnace	12.24 p.m.	1.55 p.m.	3.25 p.m.
Time taken	1 hr. 15 min.	1 hr. 20 min.	1 hr. 20 min.
Gas used, total ..	1,400 cub. ft.	1,575 cub. ft.	1,575 cub. ft.
Gas per lb. in cub. ft.	1·421	1·607	1·596
Gas per ton in cub. ft.	3,183	3,600	3,577
Temperature at draw	1,025 deg. C.	1,020 deg. C.	1,020 deg. C.

The average temperature of the waste gases was 180 deg. F. (82 deg. C.), and at no time did the thermometer register above 200 deg. F. (93 deg. C.). The average calorific value of the gas used during the day was 463 British thermal units per cubic foot.

The third day's run in the same furnace was for the purpose of demonstrating that this furnace was capable of producing and maintaining a high temperature. For this trial 80 standard firebricks were placed in the muffle and a fire-brick wall built across the opening directly behind the door. The calorific value of the gas was about 452 British thermal units per cubic foot. The temperature of the muffle on arrival was about 1,480 deg. C. This temperature was maintained, and steady, for about 1½ hours with a gas consumption of 1,350 cub. ft., equivalent to a rate of 900 cub. ft. per hour. At about noon the temperature was increased to 1,600 deg. C., and for the last hour of the run (2.30 p.m. to 3.30 p.m.) it was pushed up to 1,690 deg. C., with a gas consumption of 1,450 cub. ft. The temperature of the waste gases by thermometer at the manual was 440 deg. F. (227 deg. C.) during the earlier part of the trial, and about 600 deg. F. (315 deg. C.) during the last hour of the run.

The air and gas supply was changed over on an average every 10 minutes.

From this trial it will be seen that high temperatures can be obtained in an oven furnace of this type, which is of importance in dealing with refractories and should be especially useful to the pottery trade—but it must not be supposed that the temperatures given above can be maintained on a commercial basis; the fire-bricks were, on opening the furnace, in a plastic state and the roofs of the muffle sagging; we could not see the ports but it is most probable that they had suffered considerably.

The company have supplied a number of the furnaces on this system, which are at work or in course of erection at Manchester, Sheffield, London, &c. The results obtained under varying working conditions are stated to be quite satisfactory, and from the experience gained there appears to be no reason why the largest furnace, such as required for ships' plates, should not be a success.

Personal.—We are informed that an arrangement has been entered into between Messrs. Automatic and Electric Furnaces, Limited, 6, Old Queen-street, Westminster, S.W. 1, and Messrs. August's Muffle Furnaces, Limited, of Thorn Tree Works, King's Cross, Halifax, whereby Messrs. August will supply coke, gas and oil fuel furnaces equipped with the Wild-Barfield (patent) automatic electric-magnetic detector winding of furnaces, for correctly ascertaining the change-point of carbon steel. Messrs. August's Muffle Furnaces, Limited, will also advertise and sell the Wild-Barfield electric furnaces jointly with Automatic and Electric Furnaces, Limited. Messrs. Automatic and Electric Furnaces, Limited, have obtained the sole rights for foreign countries for the sale of Messrs. August's coke, gas and oil-fuel furnaces equipped with the Wild-Barfield patents.—For the more efficient carrying on of their business the Electric Construction Company, Limited, has opened a branch office at 166, St. Vincent-street, Glasgow. Their telegraphic address will be "Winningly, Glasgow," and telephone number "Central 1044." Mr. W. L. Winning, who has been connected with the Glasgow office of the British Westinghouse Company, Limited, for twelve years, and who is well known in the West of Scotland, has been appointed sole representative.

SWEEPING FOR MINES.*

ONE of the most difficult of the many problems with which the Navy had to contend during the great war was that of dealing with enemy minefields, and with the enormous number of moored mines laid by the Germans to afford protection to their harbours from attack, which at the same time acted as a great menace to the shipping of the Allies. As is commonly known, these sinister death-dealing instruments of war were sown in all the world's seas where the depth of the water permitted their effective use, as well as on all lines of communication used by allied vessels.

For local mine-laying the enemy employed the usual surface mine-layer, but for efforts in this direction farther afield they had to resort to submarine mine layers, and by this means were able to plant mines as far distant as the Azores and the American coast. It was up to the British Navy to neutralise as far as possible this enemy action, and for this purpose the majority of the steam trawlers and drifters were immediately mobilised to "sweep the seas," and were incorporated into that silent but plucky branch of the Navy covered by the one term "mine sweepers." The men employed on this work, needless to say, found their job a very ticklish and dangerous one in the early days, much more than at present.

The method employed originally was as follows :—

When a "dirty patch" (viz., a district yielding new mines) was located, all traffic was immediately stopped from using the waterway threatened until it had been swept and declared "clear." To effect the latter the trawler fleet would proceed to the spot, and each unit take up the station allotted to it by the senior naval officer. The vessels engaged in the trawling worked in pairs, and the ordinary steel wire warp, 2¼-in. circ. made 6 strands, each 19 wires, which each one of these vessels possessed, was made use of, *i.e.*, two boats would come together and one of them pay out to the other this trawl warp from its winch, through a lead block, over the gallows block, and thence to the gallows block of its sister ship. Both vessels would then separate until they were about 600 fathoms apart, and would proceed ahead with the warp looped between them. In order that the rope should be kept at the requisite distance below the sea surface, a special form of kite was slung over the side of each boat, and fastened to the trawl warp by a ring or special form of shackle. Immediately the boats moved ahead at equal speeds, these kites would function, thus sending the warp down to the required depth to engage with the moorings of any of the mines. The work was done on the rising tide and at the commencement of the ebb the ships resorted to a previously-arranged dumping ground, *i.e.*, where the water was comparatively shallow. As the ebb proceeded any mines which had been picked up during the trawl would generally appear on the surface of the water, and were, of course, immediately destroyed.

It will be apparent that this process was slow, uncertain, and in many respects not as effective as was desirable. For instance, sometimes a mine, although picked up by the trawl warp, for some reason or other would not show above the water at the dumping station, and when it came to heaving in the warp, it has sometimes happened that a mine has been brought into contact with the vessel, with dangerous results. It was thought that if some means could be devised whereby, on the rope engaging a mine mooring, the mine could be immediately severed, so that it would at once float to the surface, this would practically eliminate the danger attendant upon the uncertainty of the procedure hitherto adopted.

To this end particular attention was paid to the type of trawl warp used, and a new construction was specially invented by **Messrs. Bullivant & Co., Ltd.**, the well-known wire rope makers, and called in the service the "serrated sweep wire." As will be gathered from the name, this rope has a cutting edge, see **Fig. 3**, in which the upper view shows an ordinary rope and the lower view a serrated sweep rope. The latter is composed of two special-quality steel wires twisted tightly together, which are incorporated with the ordinary wires in the strands of the rope itself. They are so arranged that they exert a cutting action when coming in sliding contact with another metallic substance such as the mine mooring rope.

Speaking generally, the sister mine-sweeping vessels carry out the operation described previously, with the exception that instead of both vessels maintaining a common speed and keeping a parallel course, they alternately steam slightly ahead of each other so that the "bight" or "cod" of the sweep wire is continually altered. Immediately the sweep wire comes into contact with the mooring of a mine, the latter at once has a tendency to slide to the centre of the sweep wire. The mine anchorage and the mine itself have a "braking" or "pulling" effect against this tendency, and hence the mine mooring wire is swept with great pressure along the sweep wire towards the "bight" or "cod." This is where the serrated edge of the sweep wire does its work, and it has been shown in practice that so effective is it that the steel wire mooring rope is parted before it has moved along the sweep rope 40 ft. As regards the time taken for the cutting, instances have been known where, after a mine has been located just below the surface, the actual time taken by the serrated wire to cut it adrift has been a matter of a few seconds.

The serrated ropes were found to be so satisfactory that the idea was considerably extended, and several types introduced, to be used according to circumstances, *re* the type of vessel engaged in the work, conditions, district, &c., For heavy trawlers and paddle steamers, what is known as type A. 6 was used for a considerable time. To a large extent, however, this has been superseded by another type termed F. 2, the introduction of which was followed by remarkable results. This is a rope having a circumference of about 1¾ in., and is composed of four strands, each of five wires, plus the serrated wires before described.

For light trawlers or drifters, a somewhat similar rope is generally used, termed B. 1. The construction of this is the same, *i.e.*, four strands each of five wires, plus the serrated wires, but the circumference is only 1⅛ in.

The foregoing descriptions given apply to mine-sweeping operations where the ships worked in pairs. Means were devised whereby sweeping could also be carried out by various types of ships working singly, and for heavy work and high speed with a single ship, sweeping with an Otter or Paravane, type E. 3 sweep wire is used. This is composed of three strands each of 21 wires, and incorporated in each of these strands are three serrated edges. The circumference of the rope is about 2 1/16 in.

For light work, combined with high speed, and sweeping with a single ship, "S" type sweep wire is used. This is merely a single strand composed of 34 wires, with the addition of the three serrated wires. The foregoing are the types now generally in use, although there are others which have been invented for special purposes, which we are not yet permitted to divulge, beyond saying that they have been used as "gadgets," on our submarines to allow these vessels to cut their way through enemy defence nets.

It will be gathered from this description that, owing to the cutting action and the immediate freeing of the mines, there is no need for the sweeping vessels concerned to drag their "catches" to any agreed dumping ground.

Moreover, instead of waiting for a convenient time to effect sweeping as in the old days, these new types of sweeping wires enable the work to be carried out at all times, in all tides, and in almost all weathers, with all danger to those concerned practically eliminated. In fact, the only menace is the remote possibility of one or other of the vessels coming bow on to a stray mine, a rare occurrence. These special wires are but one of the innumerable devices which have been conceived and developed for the thwarting of enemy designs, and the value of the idea is not to be appraised from its simplicity, but its effectiveness in meeting the difficulty for which it was designed, and this is amply evidenced in the present case by results.

The accompanying sketches, **Figs. 1 and 2**, illustrate the procedure, and the effect in using present-day sweep wires.

Fig. 1. PLAN SHEWING ONE EVOLUTION BY ONE PAIR OF MINESWEEPERS.

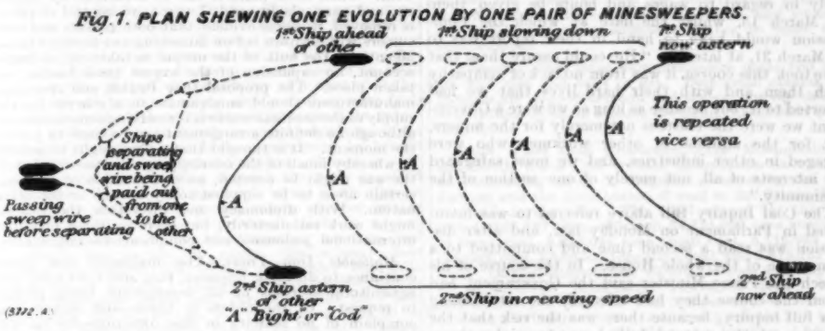
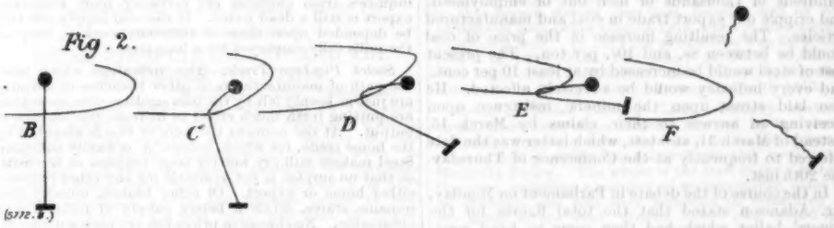

1st Ship ahead of other
1st Ship slowing down
1st Ship now astern
This operation is repeated vice versa
Ships separating and sweep wire being paid out from one to the other
Passing sweep wire before separating
A
2nd Ship astern of other "A" Bight or "Cod"
2nd Ship increasing speed
2nd Ship now ahead

Fig. 2.



B.—Sweep wire about to engage mine mooring.
C.—Sweep wire in contact with mine mooring.
D.—Mine and mooring lifted. Mine mooring rope bent round sweep wire and sliding along latter to bight or cod in background.
E.—Resistance of mine and anchorage to being pulled through the water facilitates cutting action of serrated wires in sweep rope.
F.—Sliding along sweep rope mine mooring rope is severed. Mine floats to surface and is destroyed.

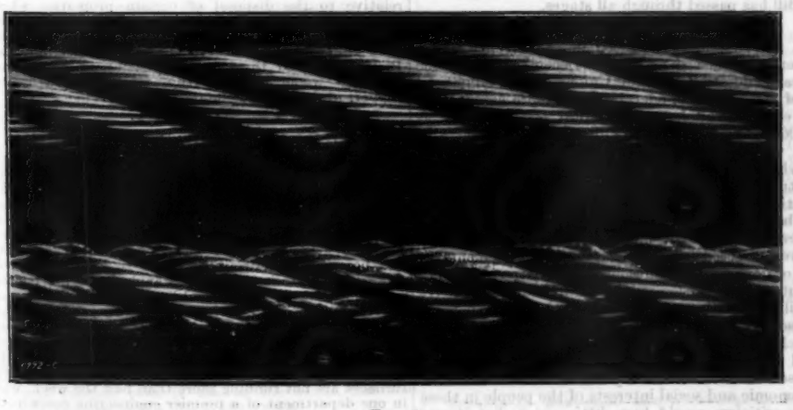


FIG. 3.

ADMIRALTY TIMBER SALES.—The Board of Trade have announced that the Controller of Timber Supplies has arranged with the Admiralty that sales of timber from Admiralty stocks direct to shipbuilders and ship repairers will cease to-morrow March 1. The Admiralty are prepared to receive from timber merchants who specialise in shipbuilding requirements offers to purchase any portion of the Admiralty stocks. Particulars of the stocks available can be obtained from the Admiralty agents, Messrs. Denny, Mott & Dickson, Ltd., London, Liverpool, Glasgow, Newcastle-on-Tyne and Cardiff. The prices for the timber will be in accordance with the revised list of maximum prices published in the *Board of Trade Journal* dated the 6th inst., less the customary allowance of 3*l.* 18*s.* per standard. All applications must be fair specification of the stocks and no selection will be allowed. Applications should be addressed to the Director of Materials and Priority, Admiralty, Great George Street, London, S.W. 1.

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INDUSTRIAL NOTES.

A DEBATE on the present industrial unrest took place in the House of Lords on the 19th inst., when Lord Emmott said that financial and business experts all assured him that there must be a hard struggle in this and succeeding years if we were to keep our place in industrial competition in the future and fight foreign competition successfully under present conditions of labour and cost, even if there was complete harmony and co-operation all the time between Capital and Labour. The capitalist knew we had been living in a fool's paradise in the economic sense during the war; he knew also that unless we could compete in the next few years successfully our commercial and financial supremacy was gone for ever. He was sure the workers were profoundly misled on the question of profiteering. The returns showed that the total excess profits made by the wealthier classes did not exceed 100,000,000*l.*, whilst in the shape of extra taxation they had paid between 150,000,000*l.* and 200,000,000*l.* From that, he argued as a genuine fact that the general effect of the war had been to reduce somewhat, rather than to increase, the net incomes of the wealthier classes of the people of this country. On the other hand, wages had been doubled, and the working classes had received from 750,000,000*l.* to 1,000,000,000*l.* more per annum than they did before the war. The report of the Income-Tax Commissioners for 1916–17 showed that, whilst the gross incomes brought under the purview of that department had increased from 732,000,000*l.* to 998,000,000*l.*, an increase of 266,000,000*l.*, the incomes from which tax was received, after deductions, had only risen some 60,000,000*l.*, or from 533,000,000*l.* to 593,000,000*l.* The enormous increase shown in the earlier figures was obviously due to the enormous increase in the number of working men who became in that year taxpayers for the first time. The net result was that the total number of supertax payers in later years was somewhat less than in the earlier years, and the total amount paid by them was only about 1½ per cent. larger.

Speaking at the same session, Lord Leverhulme said there was a deep-rooted suspicion and distrust between employer and employed which ought not to exist. It entirely arose from misunderstanding. There was no reason to be afraid of Labour. In no country were strikes more drastically and effectively dealt with than in Australia, under a Labour Government. Lord Leverhulme added that he was a convinced believer in the principles of co-partnership and had put them into operation to as great an extent as anyone. The objection of the men was that the dividends were not sufficiently high to be of interest to them. They expected profits to be higher than they were or ever could be. They had an inflated idea of what the profits were, and that was one of the causes of unhealthy unrest. The sum of 450,000,000*l.* had been mentioned as earned by excess profits. Taking that figure as the Government share and calculating what had been the excess profit of the employer, they would find that if an arrangement had been made with the workpeople at the outbreak of war, by which instead of having an increase of wages they should have the excess profits of their employers, they would have made a very poor bargain. The excess profits remaining in the hands of the employers would not have given the workpeople 4*s.* each per week, whereas the advance in wages, more often without a strike than with it, had been considerably over 1*l.* per week. The rise in wages had therefore been more than five times the increased profits to the employer. In the United States wages were much higher than in this country because the trade unions there did not place any limitation upon output. In the United States, the output per workman was considerably more than three times that of workers in this country. If all continued together in endeavouring to do their duty, they would find that the strike bogey would be shorn of its terrors and that this country would quickly raise its position as a producing country.

Viscount Haldane, at the same session, said that neither labour nor capital created wealth. Wealth was created by mind almost wholly.

This is the view which has been advanced in ENGINEERING for many years past, in series of articles in which the materialism characteristic of economics as taught in schools and text-books, and as accepted by politicians, has frequently been animadverted upon. Indeed, we may go farther and point out that Lord Haldane's observation is identical word for word with one of our own statements of the case.

On Thursday, the 20th inst., a Miners' Conference was held at 10, Downing-street, when the Prime Minister and Mr. Robert Smillie reviewed the miners' claims in detail. These include a 30 per cent. addition in wages, a 6-hour day, and the nationalisation of mines, as stated on page 218 *ante*. At the close of the conference, the Prime Minister stated that the Government, having regard to the serious effect which the concession of the demand would have upon other trades and other industries, did not feel justified in conceding it without a thorough and impartial investigation into the facts. They felt convinced that such an investigation ought to produce the necessary report before the end of March, and they therefore proposed to set up a Commission specially for that purpose. They would invite Parliament to equip the Commission with the necessary powers to command all the information which was relevant to the inquiry. If the miners did not choose to await the result of that inquiry, he would deeply regret it, but the responsibility must be theirs. (The miners asked that a reply in regard to wages and hours be given them on March 15, whilst the date at which the Commission would have to hand in their report was to be March 31, at latest.) "He could assure them that if we took this course, it was from no lack of sympathy with them and with their hard lives that we had resorted to it, but because as long as we were a Government we were the trustees not merely for the miners, but for the millions of other workmen who were engaged in other industries, and we must safeguard the interests of all, not merely of one section of the community."

The Coal Inquiry Bill above referred to was introduced in Parliament on Monday last, and after discussion was read a second time and committed to a Committee of the whole House. In the course of his speech the Prime Minister said the Government had taken the course they had selected, the establishing of a full inquiry, because there was the risk that the granting of the miners' full demands might throw hundreds of thousands of men out of employment, and cripple our export trade in coal and manufactured articles. The resulting increase in the price of coal would be between 8*s.* and 10*s.* per ton. The present cost of steel would be increased by at least 10 per cent., and every industry would be adversely affected. He also laid stress upon the miners' insistence upon receiving an answer to their claims by March 15, instead of March 31, at latest, which latter was the date referred to frequently at the Conference of Thursday, the 20th inst.

In the course of the debate in Parliament on Monday, Mr. Adamson stated that the total figures for the miners' ballot which had then come to hand were, 611,998 in favour of a strike, 104,997 against, or 507,001 majority in favour of a strike.

The Bill passed the Committee stage in Parliament on Tuesday last, the 25th inst., when the Prime Minister announced that Mr. Justice Sankey would preside over the Commission and that, barring accidents, their report would be handed in by March 20. The Bill has passed through all stages.

Mr. W. A. Appleton stated in the seventy-eighth quarterly balance sheet, dated December 31, of the General Federation of Trade Unions, that the financial side of the General Federation was more satisfactory than ever it had been. Its total reserve stood at 265,000*l.* From the trade-union point of view this was a very satisfactory position. An actuary taking the whole situation into consideration might find opportunity for criticism. No one connected with the federation had ever held that anything under 1,000,000*l.* could be regarded as satisfactory. The sum at present in reserve might easily meet all thoroughly organised and well-directed efforts to secure improvements in wages or hours, but the present tendency to rush strikes without regard to economic conditions or competitive possibilities endangered funds much larger than those possessed by the General Federation.

The Management Committee had been gravely concerned over strikes engineered for political purposes. If these strikes aimed solely at the advancement of the economic and social interests of the people in these islands criticism would have little point, but it was increasingly obvious that behind them all there was another policy.

Nothing could so surely promote future unemployment as the destruction of confidence at the present moment, and the Management Committee was prepared to give the fullest possible support to those executives who made up their minds to manage their trade unions in accordance with rule and not in accordance with the demands of selfish or excited partisans.

WOMEN'S WORK.—A conference is to be held by the Labour Research Department on the "Demarcation of Men's and Women's Trades," at 25, Tothill-street, Westminster, on Saturday, March 8, at 3 p.m. Mr. W. J. Baker (Postal and Telegraph Clerks' Association) will take the chair, and the speakers will include Mr. George Ryder (Amalgamated Society of Engineers), Mr. Alex. Gossip (Furnishing Trades Association), and Mrs. Bernard Drake (author of "Women in the Engineering Trades").

NOTES FROM THE NORTH.

GLASGOW, Wednesday.

Scotch Steel Trade.—So far as actual business is concerned the steel trade in the West of Scotland goes on steadily, there being a sufficiency of orders to keep the entire available plant fully employed for some considerable time. Plates and sections are much in demand, while the constructional work for the shipyards and general engineering purposes accounts for much of the present high rate of output. Looking ahead the prospect is rather disquieting, various unforeseen causes having given rise to a certain uneasiness. Of these, labour unrest, the cost of production and the question of a further adjustment of subsidies are undoubtedly the most serious, although the inadequate supply of pig-iron and scrap metal, and the fear of a further reduction of the supply of coal and other fuel have also to be reckoned with. Until these matters can be satisfactorily cleared up, and particularly until Government control of prices is removed, it seems evident that both makers and consumers will hesitate before launching out to any extent. Meantime, the bulk of the output is taken up on home account, no expansion of the export trade having yet taken place. The proposal that British and American manufacturers should amalgamate in a scheme for the supply of the overseas markets is receiving some attention, although no definite arrangement can be come to just at the moment. It is thought that a plan might be arrived at whereby much of the overlapping so noticeable before the war might be averted, were it possible to set aside certain areas to be supplied solely by one or the other nation. With diplomacy and discretion the scheme might work satisfactorily, but there is just a fear that international jealousies and complications might arise.

Malleable Iron Trade.—The malleable iron trade continues to do brisk business, bolt and rivet iron, and agricultural sections of all descriptions being greatly in request. Of the orders in hand—and makers can complain of no scarcity in this direction—by far the larger majority are for the home market, for, although inquiries from overseas are certainly more numerous, export is still a dead letter. If the coal supply can only be depended upon there is sufficient work to keep all the mills fully employed for a long time.

Scotch Pig-Iron Trade.—The difficulties which beset the path of manufacturers in other branches of industry are just as keenly felt by the iron smelters who, meantime are putting forth much effort to increase the tonnage of output. At the moment the bulk of this is absorbed by the home trade, for which, indeed, it is barely sufficient. Steel makers still cry out for large supplies of hematite, so that no surplus is yet available for any other purpose, either home or export. Of other brands, foundry iron remains scarce, while a better supply of forge is now obtainable. No change in prices has yet been announced.

Greenock and Shipyard Extension.—The recent purchase by Messrs. Harland and Wolff of the shipbuilding yard, so long in the possession of and worked by Messrs. Caird and Co., Limited, has aroused more than a little interest in Greenock, as the extensions which it is proposed to make mean much additional prosperity in the busy shipbuilding and sugar refining town. A heated discussion has just taken place with the Town Council relative to the disposal of certain properties which, meantime, stand in the way of the prospective improvement, and the question of dealing with the matter has been vested in a committee appointed for the purpose. Properly carried through, the scheme is one of considerable importance, worthy of the whole-hearted support of the entire community.

NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, Wednesday.

Iron and Steel.—The South Yorkshire engineering and steel trades present an uneven appearance. Marked slackness obtains in some branches, while in others output is on a maximum level, and is even then insufficient to meet current demands. The sum total of unemployment officially returned at 16,000 men, women and boys, has not declined, but is to be accounted for more by the closing down of war departments pending reorganisation on commercial lines than by acute weakness in the trade position. Increased cost of labour and material, labour unsettlement and the obscured industrial outlook, are, of course, accountable in part for existing unemployment, but not to anything like the extent represented in pessimistic quarters. Steel furnaces are not running more than half the week, while in one department of a premier engineering concern the open-hearth furnaces have been closed down indefinitely. A serious feature arises from the inability of manufacturers to quote prices for contract work required on export account. Some substantial orders have been booked, on the understanding that prices obtaining at the time of delivery shall be the basis of payment, but where this is not acceptable, valuable orders which would have assured activity in the heavy branches for some time ahead have been turned away, and in most cases have been secured by American competitors. A big demand for industrial machinery is arising from the reorganisation of munition-producing departments, and further heavy calls upon machinery makers are anticipated from the cutlery trade when that branch of industry puts into operation schemes for future working on more up-to-date lines now under consideration. Technical research, through the medium of the Sheffield University Applied Science Department, is acting as a spur to reorganisation in this particular direction. Railway axles, tyre and spring departments have sufficient orders to warrant full-time working. Slackness in this branch is the exception rather than the rule. Basic and foundry, forge and pig-iron are an even market.

Some difficulty is experienced in obtaining adequate supplies, though this complaint is more general in regard to finished iron. Makers of engineers' tools, farming, and gardening tools, and agricultural implement parts, have an abundance of work. Export trade is hampered, but a considerable portion of the output is nevertheless going abroad. File and saw-producing works are engaged at pressure in an apparently vain endeavour to keep pace with requirements. The further introduction of labour-saving machinery seems to be the only solution of the problem of how to avoid the divertion of orders into competitors' hands. The proposed purchase of the national shell factory at Templeborough, on the outskirts of Sheffield, by Steel Products, Limited, for use as steel works and rolling mills, has been cancelled by the Government's decision to use the factory for storing steel goods and other products under the control of the Ministry of Munitions.

South Yorkshire Coal Trade.—Only a very small quantity of any class of coal is available for disposal on the open market. Power and light-producing concerns, steel manufacturers, and railway companies, are alike taking as much as they can obtain to swell their reserves against the possibility of a miners' strike. Prices for all kinds of steam and manufacturing fuels are firmly held, with no likelihood of immediate reduction. Collieries are so busily engaged supplying home demands that they have little opportunity to benefit from new or revived export inquiries, though a substantial quantity is passing through the ports to allied consumers. House coal merchants could easily dispose of a bigger tonnage, the recent severe weather having resulted in heavy calls upon them. Coke is a very strong market on home manufacturing account, and shipments are on the up grade. Quotations:—Best branch handpicked, 27*s.* to 28*s.*; Barnsley best Silkstone, 27*s.* to 27*s.* 6*d.*; Derbyshire best brights, 25*s.* to 26*s.*;. Derbyshire house coal, 22*s.* 6*d.* to 23*s.* 6*d.*; best large nuts, 22*s.* 6*d.* to 23*s.* 6*d.*; small nuts, 21*s.* 6*d.* to 22*s.* 6*d.*; Yorkshire hards, 22*s.* 6*d.* to 23*s.* 6*d.*; Derbyshire hards, 21*s.* 9*d.* to 22*s.* 9*d.*; best slacks, 18*s.* to 19*s.* 6*d.*; seconds, 16*s.* to 18*s.*; smalls, 13*s.* to 14*s.*

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

The Cleveland Iron Trade.—Business in Cleveland pig-iron would be on a much more extensive scale, if foundry quality was not so scarce. Supply of that commodity continues altogether inadequate even for home use, and next to none is available for shipment abroad. Even where the iron is available it is very difficult to obtain trucks and haulage power to load the iron from the pig-iron beds, and this, of course, hampers distribution very greatly. Prospect of any material improvement of supply of rolling-stock in the near future is not at all promising. Export licences can be obtained without difficulty, tonnage is plentiful, and with freights on a much lower level than they have been this district is favourably placed, in these respects, to compete in neutral markets, but unfortunately the class of iron required for such trade cannot be had. Forge iron is quite plentiful, and is being taken up as extensively as possible. For home consumption, No. 3 Cleveland pig-iron, No. 4 foundry and No. 4 forge are all quoted 95*s.*, and No. 1 is 99*s.*; whilst for export, No. 3 and the lower qualities are 145*s.* and No. 1 is 150*s.*

Hematite Iron.—In the East Coast hematite branch interest centres in the fact that export licences are now being issued. This was not unexpected as, of late, supply for home purposes, has been more than ample. At the same time, as yet permits to ship abroad are granted with caution, surplus iron to spare for shipment is not large. Nos. 1, 2 and 3 hematite stand at 122*s.* 6*d.* for home use, and 172*s.* 6*d.* for export.

Foreign Ore.—Foreign ore shows a tendency to stiffen in price, but there is very little new business passing in view of the fact that control conditions are to be reviewed next month. Imports in fulfilment of contracts already made are on quite a satisfactory scale, and consumers have substantial stocks.

Coke.—Coke continues scarce and very strong. Demand is heavier than ever, consumers being most anxious to accumulate some stock before the miners strike notices expire. Such extra demand, however, cannot possibly be met, and indeed the normal needs of the blast furnaces are only covered with difficulty. Average furnace coke is 33*s.* at the ovens, and low phosphorus quality 35*s.* 6*d.* at the ovens.

Manufactured Iron and Steel.—Much briskness characterises the finished iron and steel industries. A good home trade is passing, and foreign demand is large and increasing. The following are among the principal market quotations to home customers:—Common iron bars, 16*l.* 5*s.*; steel ship, bridge and tank plates, 14*l.*; steel ship angles, 13*l.* 12*s.* 6*d.*; steel boiler plates, 15*l.*; chequer plates, 15*l.* 10*s.*; steel joists, 13*l.* 12*s.* 6*d.*; heavy steel rails, 13*l.* 10*s.*; and billets and blooms, 11*l.* 2*s.* 6*d.* to 12*l.* 15*s.*; whilst export quotations include: Bars, 20*l.*; steel ship, bridge and tank plates, 16*l.* 10*s.*; steel boiler plates, 17*l.* 10*s.*; chequer plates, 18*l.*; steel joists, 16*l.* 2*s.* 6*d.*; heavy steel rails, 15*l.* 10*s.*; and billets and blooms, 13*l.* 10*s.* to 15*l.*

NOTES FROM THE SOUTH-WEST.

CARDIFF, Wednesday.

The Local Markets.—The Markets this week are quiet without any material alteration from the conditions ruling last week. Arrivals of shipping over the week-end about balanced sailings, and though the congestion, particularly at Barry, is less acute, great difficulty is still being experienced in obtaining berths, and some collieries report a shortage of empty wagons, owing to the inability of the railway companies to return them with promptness. Shipments for allied destinations are being maintained, but in view of the fact that requisitioned tonnage is being returned to the owners, and that United States vessels are going home, it would not come as a surprise to the market if shipments had to be curtailed, as the Allocation Committee are experiencing difficulty in obtaining the requisite number of steamers to transport coal. Practically all sorts of large coals are tighter and difficult to secure, and this remark also applies to the better descriptions of small steams. Other qualities, however, are relatively plentiful. Licences for the export of coke are stated to be coming along better, but coke makers are deriving little benefit, as it is so difficult to get tonnage allocated for export purposes. Patent fuel manufacturers are comfortably placed as regards orders. Pitwood remains scarce, and collieries are unable to obtain sufficient timber to meet their requirements.

Newport.—Best large Monmouthshire coals and drys are well sold and hard to get. Best small steams and bunkers are in good demand and scarce, but the cheaper descriptions of small steams are plentiful without much inquiry.

South Wales Coal Production.—The Monmouthshire and South Wales Coal Owners' Association have issued an interesting series of diagrams illustrating the production and the distribution of coal in the South Wales coalfield during 1918. The total output for the year was 44,107,757 tons, of which 24,121,090 tons consisted of large coal, 8,815,040 tons small coal, 5,116,923 tons through coal, 3,239,552 tons sized coal, and 2,815,152 tons duff. Of this total output, 43,626,714 tons was disposed of as follows: Admiralty, 14,174,101 tons; home consumption, 17,932,200 tons; France (not including coal supplied through the Admiralty), 8,484,291 tons; foreign destinations, 1,966,914 tons; bunkers, 1,050,208 tons. It may be pointed out that the output for 1918 is the lowest during the past decade, and is over 13,000,000 tons below that of 1913, when it amounted to 57,000,000 tons. In 1914 the production was 53,880,000 tons; in 1915, 50,443,000 tons; in 1916, 52,080,700 tons; and in 1917, 48,507,000 tons. There is, therefore, a decrease of 22·8 per cent. as compared with 1913.

Strike of Welsh Colliery Clerks.—Colliery clerks in South Wales show signs of being affected by the general industrial unrest, and for the first time in the history of the coalfield a strike has taken place this week in the Rhondda Valley. The whole of the staff of the Cambrian Combine, including a number of women clerks, came out on Monday, and had they persisted in remaining out the whole of the week, almost 10,000 men would have been rendered idle, as it would have been impossible to keep the collieries going without the necessary clerical work being kept up. The men belong to the National Union of Clerks, whose local organiser advised them to resume work as they had embarked on an illegal strike, and their case was already being considered by the owners and the union representatives. Upon being pressed to do so, they consented to resume work to-day pending the meeting of the Conciliation Board on Friday.

THE NEON SPECTRUM.—Having measured 55 lines in the neon spectrum by means of the interferometer in the United States Bureau of Standards, Kelvin Burns, W. F. Meggers and P. W. Merrill recommended neon as a standard substance for spectroscopic work (Scientific Paper, No. 329). The strength and distribution of the lenses in the region 5852 to 7438 Angström units are particularly recommended for this purpose, further also the ultraviolet group between 3369A and 3520A and a few lines on the infra red. The extreme range over which measurements have been made extends from 3369A to 8495A. The measurements of strong lines are considered correct within one part in several millions, or within less than nine-tenths of the width of the line; in some measurements three pairs of interferometer plates were used. Further measurements have been effected over 189 fainter lines in the visible and infra red spectrum by means of a concave grating; the accuracy claimed for these is 0·01 or 0·02A. It is pointed out that the strong lines show the constant differences in wave-lengths observed by Watson.

STRAINS IN QUENCHED AND COLD-DRAWN BRASS.—Experimenting with cylinders of brass, 20 mm. or 40 mm. in diameter and 100 mm. in length, A. Portevin (*Comptes Rendus*, December 23, 1918) finds that these cylinders, quenched in water after heating up to 760 deg. C. or 850 deg. C., displayed peculiar internal stresses when tested 15 days after quenching. The exterior of the cylinder was in a state of compression, the longitudinal stress amounting to about 10 kg. per square millimetre. Below the surface these stresses decreased and changed sign in the interior of the cylinder, finally a state of tension of about the same magnitude being observed at the centre of the bar. The phenomena appeared reversed in experiments with cold-drawn brass. The drawn brass developed surface crusts, was easily broken by bending, and showed tension on the surface and compression in the interior; the stress values were higher than in the previous case and more unequal, the tension stress amounting to 24 kg. per square millimetre, the compression to 11 kg. per square millimetre. By drawing quenched bars, instead of annealed bars, the limits of brass-drawing might be extended, Portevin suggests; but he does not say that he has actually made the experiment.

NOTICES OF MEETINGS.

THE JUNIOR INSTITUTION OF ENGINEERS.—Friday, February 28, at 7.30 p.m., at 39, Victoria-street, Westminster, S.W. Paper by Mr. N. Pemberton (Member), "Drawing Office Systems."

THE PHYSICAL SOCIETY OF LONDON.—Friday, February 28, at 5 p.m., at the Imperial College of Science, Imperial Institute-road, South Kensington, S.W. Agenda: (1) "On Simplified Inductance Calculations, with Special Reference to Thick Coils," by Mr. Philip R. Coursey, B.Sc., A.M.I.E.E.; (2) Demonstration of Some Acoustic Experiments in Connection with Whistles and Flutes, by Mr. Ralph Dunstan, Mus.Doc.; (3) Demonstration of a New Polariser, by Mr. G. A. Brodsky, M.A.

THE BRITISH FOUNDRYMEN'S ASSOCIATION: LANCASHIRE BRANCH.—Saturday, March 1, at 4 p.m., in the College of Technology, Manchester, Mr. Ben Hird, of Peterborough, will give a paper on "Practice Notes on Some Jolt Ramming Jobs."

THE ROYAL SOCIETY OF ARTS.—Tuesday, March 4, at 4.30 p.m., Colonial Section: "Science and Industry in Canada," by Professor John Cunningham McLennan, O.B.E., Ph.D., F.R.S., Scientific Adviser to the Admiralty. Alan A. Campbell Swinton, F.R.S., Chairman of the Council, will preside. Wednesday, March 5, at 4.30 p.m., Ordinary Meeting: "The Rubber Industry—Past and Present," by Mr. Benjamin Dawson Porritt, M.Sc., F.I.C., Chief Chemist, North British Rubber Company. Professor Wyndham R. Dunstan, C.M.G., F.R.S., Director of the Imperial Institute, will preside. Thursday, March 6, at 4.30 p.m., Indian Section: "The Need for a History of Bengal," by Mr. W. R. Gourlay, M.A., C.I.E., I.C.S. The Right Hon. Lord Carmichael, G.C.S.I., G.C.I.E., K.C.M.G., will preside.

THE JUNIOR INSTITUTION OF ENGINEERS: NORTH-EASTERN SECTION.—Tuesday, March 4, at 7.15 p.m., at the Mining Institute, Newcastle-on-Tyne, a paper on "Electrical Disturbances in Supply Systems," by Mr. L. C. Grant.

THE LIVERPOOL ENGINEERING SOCIETY.—Wednesday, March 5, at 8 p.m., at the Royal Institution, Colquitt-street, a paper will be read by Mr. H. Mawson, B.Sc. (Lond.), Wh.Sc., Assoc.M.Inst.C.E., entitled, "The Manufacture of Brass Rods."

THE INSTITUTION OF ELECTRICAL ENGINEERS.—Thursday, March 6, at 6 p.m., at the Institution of Civil Engineers, Great George-street, Westminster, S.W. Lecture on "Dielectrics in Electric Fields," by Mr. G. L. Addenbrooke, Member.

THE ROYAL INSTITUTION OF GREAT BRITAIN.—Friday, March 7, at 5.30 p.m., a discourse will be delivered by Professor H. C. H. Carpenter, F.R.S. The subject will be "The Hardening of Steel." Afternoon lectures, at 3 p.m.: Tuesday, March 4, Professor H. Maxwell Lefroy, M.A., F.E.S., F.Z.S., on "How Silk is Grown and Made," (2) Mulberry Silk (Lecture III); Thursday, March 6, Mr. Charles Aitken on "Rossetti" (Lecture I); Saturday, March 8, Professor Sir J. J. Thomson, O.M., LL.D., D.Sc., on "Spectrum Analysis and its Application to Atomic Structure" (Lecture I).

THE INSTITUTE OF METALS.—The annual general meeting of the Institute of Metals will be held, by kind permission, in the rooms of the Chemical Society, Burlington House, Piccadilly, W.1, on Tuesday and Wednesday, March 25 and 26, 1919. The meeting will commence at 4 p.m. on both days. On Tuesday, March 25:—The report of the Council on the work of the past year will be presented by the President. The Fourth Report to the Corrosion Research Committee will be presented by Captain Bengough and Dr. Hudson and discussed. At 6.30 p.m. the meeting will be adjourned and at 8 p.m. the discussion of the fourth report will be continued, and a selection of communications will be read in abstract and discussed. On Wednesday, March 26:—A selection of communications will be read in abstract and discussed. At 6.30 p.m. the meeting will be adjourned and at 8 p.m. general discussion on "The Relation of Science to the Non-Ferrous Metals Industry" will be opened by Dr. W. Rosenhain. 10 p.m. the meeting will be brought to a conclusion. Communications.—The following communications are expected to be submitted in the order given: Tuesday, March 25: (afternoon session, 4 p.m. to 6.30 p.m., and evening session, 8 p.m. to 10 p.m.):—(1) Fourth Report to the Corrosion Research Committee, by Captain G. D. Bengough, D.Sc., M.A., Member, and O. F. Hudson, D.Sc., Member (London). (2) "The Properties of some Copper Alloys," by W. Rosenhain, D.Sc., F.R.S., Vice-President, and D. Hanson, M.Sc., Member (Teddington). (3) Note: "Metallurgical Information Required by Engineers," by Lieutenant-Colonel C. F. Jenkin, R.A.F., M.A., M.B.E., Member (Oxford). Wednesday, March 26 (afternoon session, 4 p.m. to 6.30 p.m.):—(4) "The Micrography of Aluminium and its Alloys," by D. Hanson, M.Sc., Member, and S. L. Archbutt, F.I.C., Member (Teddington). (5) "Effect of Work on Metals and Alloys," by Owen W. Ellis, M.Sc., Member (London). (6) Note: "The Influence of Cold Rolling upon the Mechanical Properties of Oxygen Free Copper," by F. Johnson, M.Sc., Member (Birmingham). Wednesday, March 26 (evening session, 8 p.m. to 10 p.m.):—(7) General discussion on the relation of science to the non-ferrous metals industry, opened by W. Rosenhain, D.Sc., F.R.S., Vice-President, with paper on "Science and Industry in relation to Non-Ferrous Metals," and followed by (8) Note: "The Relationship between the Laboratory and the Workshop," by W. R. Barclay, Member (Sheffield), and (9) Note: "The Scope of the Works' Laboratory," by F. C. A. H. Lantsberry, M.Sc., Member (Birmingham).

ANNEALING AND HEATING FURNACES FIRED BY TOWN GAS.

CONSTRUCTED BY THE DAVIS FURNACE COMPANY, LUTON.

(For Description, see Page 272.)

Fig. 3.

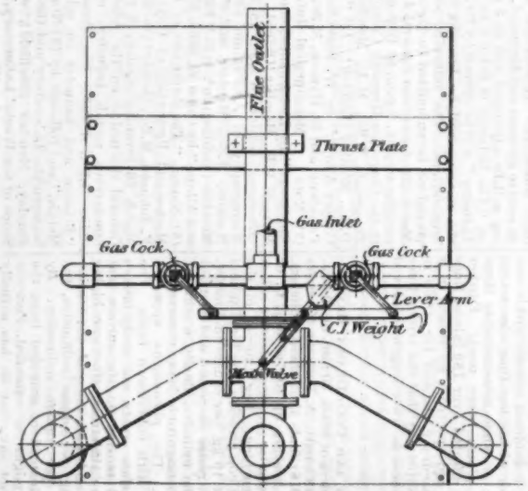
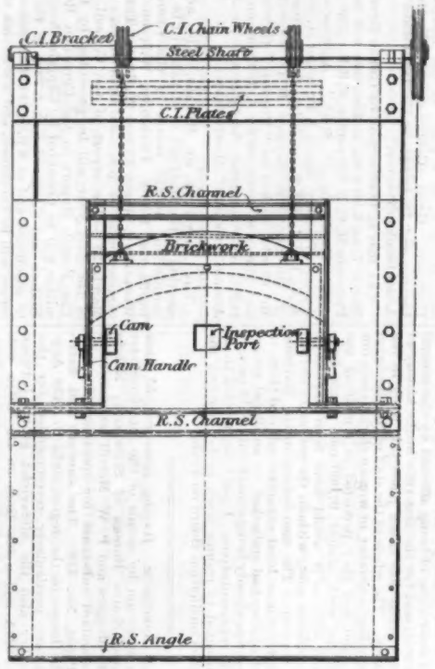


Fig. 4.



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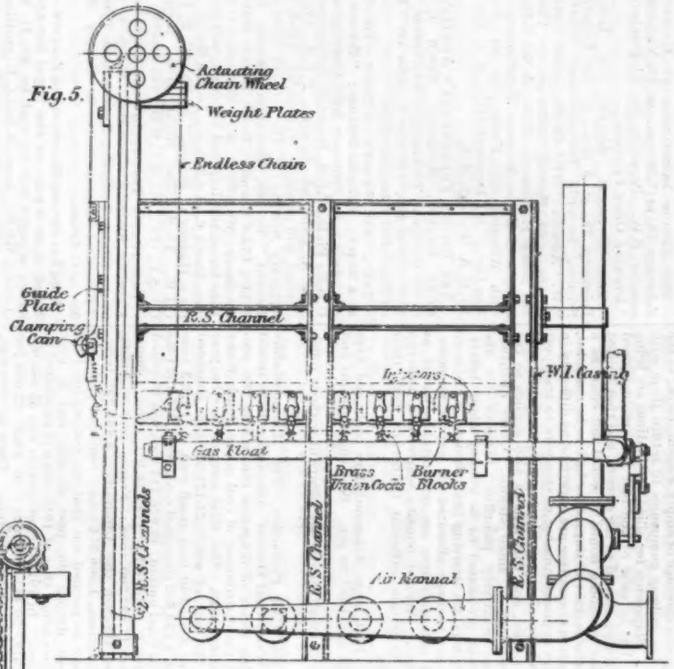

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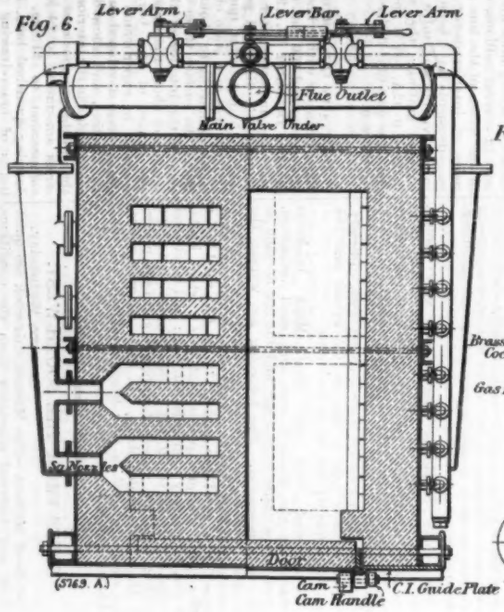

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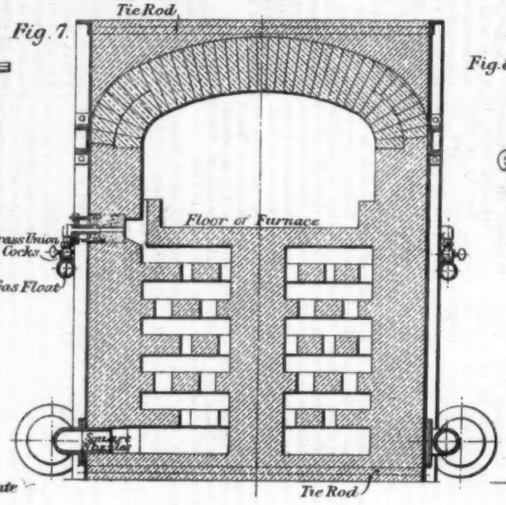

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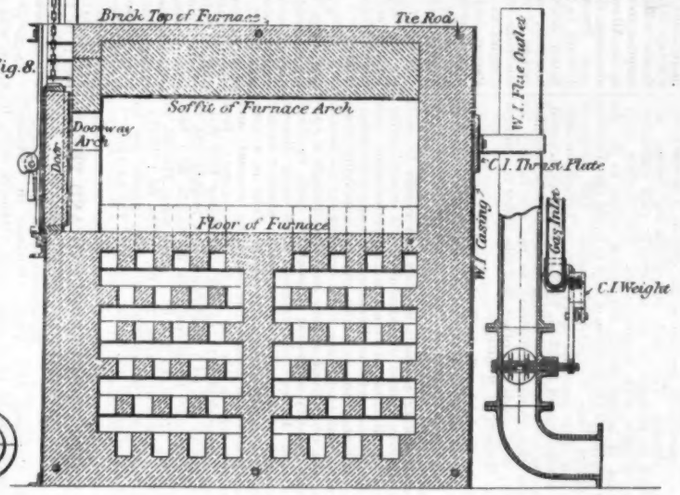

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NOTICE TO NON-SUBSCRIBERS.

In view of the restrictions now imposed by the Government on the importation of paper and the consequent shortage of supplies, Newsagents will not have copies for chance customers: therefore readers who wish to be sure of obtaining "ENGINEERING" each week should place an order for the Journal with a newsagent or bookstall clerk.

NOTICES OF MEETINGS.

Notices of Meetings to take place during the present and next week will be found on page 275.

ENGINEERING.

FRIDAY, FEBRUARY 28, 1919.

AN INDUSTRIAL PARLIAMENT.

SOMETIME in the latter half of 1917, a year which will in the future be memorable for many things, not least because it was then that reconstruction first became prominent, the idea of a permanent parliament of industry received some ventilation in the pages of the contemporary press. Like many other projects it was set aside and for a time dropped out of notice because other and more urgent matters occupied the Government and the public mind. The Whitley proposals clearly foreshadowed an extension of the Joint Councils to some such end, and now the Government is calling a national conference of employers and workers as a means to settle the industrial crisis which has resulted in the events of the past few weeks. This parliament of industry assembled yesterday, and may very well become a permanent institution upon which all parties to the industrial question may find representation and a means of adjustment. Just as minor differences find localised adjustment by the means of a Works Committee, as the District Joint Council deals with matters pertaining to a given territory, so a National Conference should provide a means to adjust those problems which affect industry *per se* in a national sense. It is obvious that periodical recurrence of the events of the last few weeks and the more serious threatened disorganisation which now clouds the industrial sky must, unless settled in an amicable manner, lead to industrial bankruptcy and national insolvency. Assuming for a moment that such a conference has a successful outcome, considerable time has already been wasted and much public inconvenience caused, to say nothing as to the delay in winning stable conditions for the future. It is curious that the suggestion in the first instance, and the practical steps now afoot to give effect to the idea, should have been so long in maturing, especially when it is remembered that it was this country which founded parliamentary institutions and whose tendency to the committee idea is peculiarly national in character. It is also curious that definite co-operation in industry with its apparent advantages should have been so slow in evolving.

As a matter of fact, industrial enfranchisement is hardly yet in being, although the framework upon which it can be built is gradually being reared; and just as avoidance of international disaster known as war is leading to the institution of a League of Nations, so the avoidance of industrial strife may very well lead to a League of Industry. Already steps are being taken to ensure that competitive nations shall secure rational and comparable standards of life to workers in similar industries, so that trade shall not be based upon sweated labour, and undercutting by means of starvation wages.

The tie of mutual interest between man and management has only just secured recognition. The feeling during recent years has been that of mutual aversion—and each has been organised for defence against the other. Aversion has a greater binding effect upon a multitude of units than even interest, for in the face of a common agressor men of diverse temperaments find identity of purpose. Industrial unrest, so termed, was prominent long before the war. During the war it was largely suppressed by the aversion felt for the enemy; national necessity made a common bond, and patriotism accepted much that was refused under peace conditions. It is realised by practically every thinking man that industrial interests are not confined to a particular class; the great bulk of moderate opinion is turning to the recognition that industry and its workers, however paid or rewarded, form a co-partnership, its interests are not antagonistic and opposed, but are identical. The intimate relationship which formerly existed between master and man, and which in isolated instances survives to-day, played no unworthy part in past development. Yet for many years now the feudal idea, which centered in paternal management, has been an antique survival and present conditions do not favour its retention. The more progressive concerns do not attempt the impossible; they recognise it is useless to be patriarchal, although they make definite effort to cultivate an atmosphere favourable to amicable relations.

Industrially we are now very much in the position that many Continental countries were politically during the Middle Ages. Then every baron, and every free town, claimed the right of carrying on private war. On the slightest pretext, or without any other pretext than the desire to acquire their neighbour's property, they entered the field. If the fighting had been confined to those who had a direct interest in the struggle the matter would not have been so serious. But the war brought death and desolation to thousands who had no concern in it, and probably knew nothing of its cause. So great was the harm done that kings bent all their energies for hundreds of years to break the system and to oblige gentle and simple alike to bring their grievances before the Courts, instead of seeking redress by their swords. In France it was not until Louis XIV was firmly established on the throne that the nobles were finally made amenable to the law, and even then they managed to retain many of their feudal rights until these were abolished at the Revolution.

In this country the power of the barons was broken in the Wars of the Roses, and thereafter law reigned supreme. But as regards industrial matters it was a very one-sided affair. The employer could discharge his men as he pleased, but anything like an organised strike was dangerous to the leaders as rendering them liable to charges of conspiracy in restraint of trade. It was not until the reign of Victoria that the law was altered and the State professed to confine itself to keeping a ring while capital and labour fought out their quarrels. As long as strikes were local no great harm was done. Both parties suffered, but the loss was mainly confined to the combatants, who represented a very small proportion of the industry. Now the sectional strike is being overshadowed by the national strike, and whatever loss or suffering it may entail to the actual combatants will be a mere trifle to that it will bring to millions who have no interest in the matter. A strike is not an infraction of the law, and there is no power of compulsory arbitration, so that the Government has no direct method of enforcing a continuance of work. All that it can do is to foster the creation of an intelligent pubic opinion, and experience shows no great strike is likely to be successful if it excites the reprobation of the general community. Unfortunately it is seldom that the public understands the real merits of a dispute; indeed, we might go further and say that often the combatants have no knowledge of any side of the case but their own. It is to remedy this state of affairs that the National Conference has been summoned. All the interests likely to be affected by strikes are invited to make out the best case they can and to submit it to the criticism of the rest. If they refuse to plead their cause it will be understood that it lacks justification and is only an attempt to secure undeserved benefits at the expense of the community. If their cause is good it is certain of a respectful hearing, and if, as is most likely, it contains both good and bad features, it will be strengthened as its advocates are taught by criticism to prune the excrescences and moderate their demands to what they can ask with justice. But the chief good to be anticipated is the enlightenment of the public. Every one is anxious that the conditions of labour should be ameliorated, but few understand how far this can be carried. If the

debates raise an interest in economics, if they show the man-in-the-street what is the source from which wages can be paid, and if they convince the workers that they can only thrive if capital is also successful, then we shall see the dawn of a new era. This does not mean that many of the ideals of the unions cannot be attained, but it does mean that no man can permanently receive more than he earns and that high wages are only possible with high efficiency.

An industrial parliament charged with the control of industry must include in equal shares, representation of all parties in its economy. It is not an easy matter for the wildest extremist to fly in the face of an overwhelming majority. The business man is usually a reasonable individual willing to adjust himself to conditions, while the intelligent employee realises that risks assumed and capital invested must earn a return suitable to the hazard and outlay. Many are the cut-and-dried solutions promulgated, but just as in political matters continuous adjustment is made from time to time, so in industrial matters real representation and open debate should provide redress while putting the extremist out of court. It is fairly obvious to the meanest intelligence by now that undue exploitation of labour or excessive profits will not be suffered. To reduce standards of life below an efficiency point, in order to compete in export trade, is quite irrational; it is for one thing a reflection upon the capacity of management. Sweated labour is the resource of the man who does not understand the art of cheap manufacture, and results in breeding and rearing an inferior race. Yet numbers of otherwise sane manufacturers believe that low wages are essential to industrial supremacy, forgetting the outstanding case of the United States of America. Real industrial progress is quite consonant with high wages, provided that in return real effort is obtained. Such wages place a premium upon ingenuity; modern methods, the more economical employment of human material, cause the extension of mechanism and give increased productivity. There is a notion prevalent that captains of industry, so called, are its only true representatives; at all events advice seems only to have been sought from the heads of firms and from Labour leaders, neither of whom are sufficiently in contact with actual industrial life. If the Whitley proposals are adopted in earnest it will be found that among minor and major executives there is a wonderful fund of knowledge and experience not yet utilised which the Whitley scheme, properly framed, can set free. All the brains do not occupy the titular posts as their occupants, if honest, will admit. The objection urged is that discipline will suffer, but if the interests of the two parties can be rendered identical this does not follow of necessity. Anyhow, it is vital to establish a clearing house for trouble; most strife is avoidable by mutual adjustment and a policy of give and take, and it is worth while to discover if there is not more intelligence in the industrial ranks than usually gets credit. In the absence of knowledge and fair discussion ignorance must prevail, and it is ignorance which needs exorcising on both sides of the industrial equation. In the past, when temper was on a raw edge and trouble imminent, there was little surface indication, and when the trouble matured arbitration was impossible, for it needs calm reasoning and a dispassionate atmosphere.

There are many things upon which the proposed parliament of industry could advise with authority. Many matters delegated to various State departments might find a tribunal in the new assembly, while obviously its main activity would be the relationship between the partners in industry. It could provide opportunities for debate upon industrial economics, and welfare of the workers; it could condemn the bad employer; and the recalcitrant worker, restriction of output and fairness of payment commensurate with living costs and responsibility would all engage its attention. Health insurance, unemployment compensation, labour exchanges, arbitration in disputes would all be in its custody. A conference in periodical session would find plenty to occupy its attention.

If the present experiment should prove successful in educating the public and gaining the confidence of both capital and labour—rather an optimistic aspiration—we may look forward in the future to its forming the germ of a permanent arbitration court whose decisions would be binding, and who would have the power to inhibit private industrial warfare. But before that can occur mutual aversion must be replaced by mutual interest. The cards must be laid upon the table, and each side must study the other's position. Labour must realise that already it receives the greater part of the joint earnings of itself and capital, and that any further share, unless the result of increased efficiency on both sides, would kill the goose which lays the golden eggs. Capital already recognises that the worker is determined to gain a better life, and it must be ready to comply with the demand as far as it is feasible. Both sides must reconcile themselves to a far more strenuous life than they have hitherto led. If the workers have shorter hours they must turn out more in the reduced time, and this they cannot do unless the factory equipment and management are in some cases vastly improved. As a nation we hate steady thinking and prefer to muddle through but in the future we shall have to amend our ways in this respect, and lay out our plans with greater method and care. Until this is done, and not till then, can we hope that all classes will work amicably together, and enjoy a joint prosperity.

The outcome of the new conference will be anxiously watched for all the peace of the future depends upon its constitution, its methods, and its results. Any attempt to introduce methods other than strictly just and impartial is going to aggravate not ameliorate; the time is past for throwing dust in the eyes of any section of the industrial community, whereas character and real consideration will go far to make a permanent settlement of the most anxious problem of the present time.

THE LIGHTING OF RAILWAY PREMISES.

Now that the general restrictions on public lighting imposed on account of the visits of enemy air craft have been relaxed, owing to the termination of hostilities, it is probable that many concerns will be occupied with schemes for improving lighting, and by improved lighting we do not necessarily mean increased illumination, but rather a better distribution of light. In the past the tendency has been rather to employ each increase in the efficiency of lighting methods rendered available by the progress of science in raising the standard of illumination, but if this standard is sufficiently high already there is no reason why improvements should not be used to effect a reduction in cost. At the present moment this is particularly true owing to the need for extreme economy in fuel consumption, and it seems highly probable that in the future considerations of fuel economy will be forced upon every member of the community by the increased cost of that commodity.

In railway premises, which we are now considering, light must be provided to ensure the safety of the public and to enable the staff to carry on its duties safely and expeditiously. Lighting is thus to be considered from a purely utilitarian point of view, since it is not generally arranged to attract customers as is frequently the case with places of entertainment for instance. These views, which we fully endorse, are expressed in a very useful and interesting paper by Mr. A. Cunnington, the lighting engineer to the London and South-Western Railway, dealing with railway lighting and maintenance, which he read at a recent meeting of the Illuminating Engineering Society.

In the general problem too much attention can hardly be given to the question of maintenance, and to show the importance of this matter Mr. Cunnington mentions that on one of the trunk lines in this country maintenance costs amounted to about one-fourth of the cost of the illuminant in normal times; at the present time the ratio would be nearer one-half. Standardisation, of course, largely affects the question of maintenance, and *ceteris paribus*, that system which permits of the highest degree of standardisation of burners, fittings, &c., is the best for railway work. With modern gas lighting the tendency is to standardise a rather small mantle, generally the "Medium" or No. 2 size, and if larger units are required, to use two or more of this size together. Small mantles are certainly stronger and more easily handled than large ones, and they also appear to be less affected by variations in the pressure and quality of the gas supplied. Standardisation of electric lamps for use on a main line railway is greatly hampered by the fact that energy is supplied at different voltages at different parts of the system. On the line above mentioned, for instance, 12 different supply pressures, varying from 100 volts to 600 volts, are in use. These include the complete series of pressures from 200 volts to 250 volts in steps of 10 volts, and it is therefore not surprising that, in order to reduce lamp stocks, over-running or under-running is resorted to for certain intermediate voltages. In the case of the modern gas-filled tungsten filament lamps Mr. Cunnington finds under-running by 1 or 2 per cent. a distinct advantage from the point of view of the life of the lamps, though there is, of course, a slight drop in efficiency. Until comparatively recently these lamps were only supplied for comparatively low voltages, so that series running was frequently resorted to. This, of course, considerably affected the question of maintenance, as a number of lamps of special voltages had to be stocked, and for good series running it was necessary to replace all the lamps in a series if one failed. The lamps, however, are now supplied for higher voltages so that they can usually be run in parallel, and in this connection a curious difficulty has been encountered. It is found that if a lamp fails it generally blows the fuse and extinguishes all the lamps in circuit. The trouble appears to be due to the fusing together of the leading-in wires of the lamp. This did not occur with lamps run in series, and it can probably be avoided by the lamp-maker by some modification in the design. With these lamps quite sufficient protection for outdoor use can be provided by the reflector, and it is therefore unnecessary to use an outer globe. This feature, which makes for considerable economy in maintenance, may also be extended to indoor gas burners, the slight theoretical reduction in efficiency being more than compensated for by the absence of globes which soon get dirty in most situations on a railway system and thus obstruct the light.

Coming now to the lighting of station platforms, Mr. Cunnington gives some interesting figures of measured values of illumination that have been found satisfactory under different conditions. Three classes of station are dealt with:—(1) Terminal stations, completely covered by high roofs; (2) important junctions having low roofs over the platforms only and (3) less important and wayside stations which usually have a short length of roof and "beacon" lighting beyond. For the three classes of station it is suggested that satisfactory values for the minimum horizontal illumination, measured at a height of 3 ft. above the platform, would be 0·5, 0·25 and 0·035 foot-candles respectively. It is, however, necessary to specify not only the minimum illumination, but also the ratio of maximum to minimum, and these ratios are given as 3, 10 and 13, respectively, for the three types of station above referred to. The latter figures, of course, determine the uniformity of lighting, and it is highly desirable to secure the greatest possible degree of uniformity since experience proves that a much lower average illumination will suffice when the lighting is uniform than when it varies greatly from point to point. As an example of this Mr. Cunnington cites a case in which arc lamps spaced 50 ft. apart were replaced with tungsten lamps spaced 20 ft. apart. With the arc lamps the illumination, which measured immediately under a lamp was about 4·3 foot-candles, fell to less than 0·2 foot-candles, half-way between two lamps. With the tungsten lamps, on the other hand, the illumination ranged from about 0·6 to 0·9 foot-candles, and was therefore much more satisfactory. For ticket collecting barriers special local lighting should be provided, as otherwise an unnecessarily high standard of general illumination would have to be maintained; about 2 foot-candles appears to be a satisfactory degree of illumination for this purpose. Timetables and station nameplates also require special illumination according to circumstances.

"Beacon" lighting, in Mr. Cunnington's opinion, is quite satisfactory for wayside stations, since the light emitted from the train itself supplements the illumination just when it is most required. At stations of this class intervals between trains are usually long, and the amount of traffic would rarely justify the installation of an elaborate system of controlled lighting, which would give a high degree of illumination when a train was standing at a station and permit of a reduction between trains. Such stations are generally lighted by means of oil lamps, and something has been done with a form of lamp having an ordinary duplex burner which can be partially extinguished by pulling a chain, so that the oil consumption is reduced to about one-fourth of the normal amount. Each lamp has to be attended to individually with this arrangement, but with long intervals between trains a considerable degree of economy in oil consumption may be effected. Acetylene, petrol-air gas, and vaporised oil lamps are available for use at stations, which, although remote from a gas or electric supply, may be situated at a junction of some importance.

The lighting of railway goods sheds is a problem of some difficulty, and, owing to the very diverse conditions existing, it is by no means easy to fix suitable standards of illumination. On receiving platforms, where labels have to be read, consignment notes checked, &c., high and uniform illumination is necessary. Local lights are also necessary near checking desks and scales. For loading platforms a somewhat lower standard of illumination will suffice, but it is desirable to arrange the lighting so that some of it reaches the interiors of box wagons. In any case it is obvious that in setting a standard for illumination it is necessary to consider the situation of the shed and the class of traffic dealt with. Sheds in large towns may be in use almost continuously, whereas those at a wayside station may rarely be used after dark for the greater part of the year. A classification similar to that suggested above for stations may therefore be applied to goods sheds, and if this is adopted suitable values for the minimum horizontal illumination in a plane 3 ft. above the loading platforms are 1·5, 0·45 and 0·08 ft.-candles, respectively, for the three classes of sheds. The ratios of maximum to minimum illumination suggested by Mr. Cunnington for the three classes are 5, 5 and 16 respectively. Practical considerations, of course, often interfere with the effective arrangement of lighting. For instance, it commonly happens that the available headroom is insufficient to allow high-power lighting units to be suspended at a proper height. Another difficulty occurs in connection with the local lighting of desks and scales owing to the vibrations and shocks arising from the rapid handling of heavy goods. For this reason flat-flame gas burners have been employed, but the author of the paper is of the opinion that pendant incandescent burners provided with anti-vibration fittings would prove satisfactory. Modern metal-filament electric lamps suspended by flexible cords are also capable of withstanding severe vibration.

In open goods yards it is practically impossible to provide a measurable standard of illumination between the rows of high wagons. Generally there is insufficient room to fix lamp posts between all running roads, and in any case the cost would be prohibitive. Actually the shunter uses a hand-lamp for reading labels and shunting instructions on the sides of the wagons, so that it is unnecessary to provide sufficient general illumination to enable this to be done. What is required is sufficient general illumination to enable the movements of trucks to be distinguished readily, combined with a much higher local illumination for working areas, such as the "shunting neck" or the series of points leading into sidings in a gravitation yard. Some experiments carried out by Mr. Cunnington show that a vertical illumination of only 0.01 ft.-candle on the end of a wagon enabled it to be seen clearly, and he therefore suggests that this would be a suitable minimum for any part of a yard where shunting is carried on. The illumination should be measured in a vertical plane at right angles to the direction of the siding at a height of 3 ft. above the ground, this being approximately the height of the buffers. This figure for the general illumination is suggested for all classes of yards, as on it the safety of the shunter depends. For the working areas in which a higher standard of illumination is required, somewhat different treatment is necessary in the cases of the small yard of a country station and that of an important junction or terminus. For the former class an illumination of 0.05 ft.-candle is suggested for the working areas, and for the latter class an illumination of 0.25 ft.-candle. Both are minimum values of vertical illumination.

In dealing with engine sheds, where an element of danger occurs owing to the movements of engines and the presence of inspection and wash-out pits, Mr. Cunnington thinks the minimum illumination should not fall below 0.05 ft.-candle. Good vertical illumination is important in engine sheds to enable the cleaners to do their work efficiently, and for this reason open-pattern reflectors are most suitable. Owing to the dirt and smoky atmosphere the fittings used must be such as can be easily cleaned, and where electric lighting is installed porcelain lamp holders may be employed with advantage to resist the ever-present corrosive fumes.

The paper also touched upon the lighting of subways, booking offices, and situations in which a mixture of daylight and artificial light has to be employed, each of which presents a special problem for the illuminating engineer to solve. In them, as in the cases we have dealt with more fully, the main object is to provide sufficient light for the convenience of passengers and for the safety and efficient working of the railway servants. This must also be done with a reasonable expenditure for illuminants and maintenance. Another important matter was referred to in the conclusion of the paper, and that is the necessity for giving careful attention to lighting at the inception of all new schemes, so that the best illuminating devices may be included as an integral part of the scheme and not, as is frequently the case, be added later, apparently, as an afterthought.

THE WAGE PROBLEM IN INDUSTRY.

On Wednesday Mr. W. L. Hichens, chairman of Messrs. Cammell Laird and Co., Limited, spoke before the Royal Society of Arts on the wage problem. Mr. Hichens is known to be a very large-hearted man, who takes a keen interest in the progress of the working classes and sympathises with their aspirations for a better standard of living. Therefore, when he points out that there are limitations beyond which increases of wages and reductions of hours of labour cannot go, it is not that he is trying to conserve the profits of capital, but that he is thinking of the prosperity not only of labour and capital, but also of the general community. He takes his stand in relation to industrial affairs on the basis of morality. He holds that ultimately all industrial questions, as well as all other questions affecting human relations, resolve themselves into moral problems, and how far we succeed in solving these questions depends on the degree of moral consciousness to which the community has attained.

There is no doubt that the past 50 years have seen a great quickening of moral consciousness in the nation, in spite of the constant complaint that the churches are growing more and more empty. The poor, the weak and the unfortunate receive vastly more consideration than they did, and the responsibilities of the community in regard to them are fully acknowledged. There is, however, little sign of moral consciousness in the struggles of labour and capital. According to Mr. Hichens, neither side is willing to surrender a tittle of its so-called rights—the right to keep whatever its strength enables it to acquire. This is quite natural, for it is not given to men to be just judges in their own affairs. The ruling principle of law is that the judge must be impartial, and must apply principles laid down for him by the law makers. Mr. Hichens would put the Government in the position of a judge because "the demands of the wage-earners in each industry cannot be settled in isolation from each other, or independently of the claims of capital. For an increase in wages in one trade involves an increase in others, and in time these increases react on capital, which requires a higher rate of interest. While, therefore, the organisations of employers and employed in each industry should be responsible in the first instance for negotiating all wage problems, the Government should exercise the right of reviewing all decisions from the wider standpoint of the general interest, and should regulate both the profits on capital and the wages of labour in order that a due proportion should be observed." In making this suggestion Mr. Hichens has in the back of his mind the possibility of capital and labour combining to prey upon the consumer. This, of course, is a possibility, but so far we have seen little sign of it, and it can never become universal in a country which lives largely on its exports. Of course prices go up with wages, but that is mainly because if they did not factories would have to close down. Roughly, prices and wages have both doubled during the war, while the reward of capital has not advanced in anything like the same proportion. The value of pre-war securities has fallen from 20 per cent. to 40 per cent., while dividends are taxed 30 per cent. after the excess profit tax has been levied.

It is undoubtedly very difficult to apply the moral law to such a condition of affairs. At the first sight co-partnership seems to promise a solution of the trouble, but, as Mr. Hichens points out, this would only lead to greater discontent, for the worker in a struggling concern would get less pay than one in a successful firm. So far the solution of the wage problem is not in sight, and all that we can say with certainty is that it is the duty of Government to safeguard the interests of the community when an attack is made on these in order to bring pressure on either of the contending parties.

If capital and labour cannot carry on their struggles without injuring non-combatants the State must intervene. The case is similar to that which brought the United States into the war. Its citizens were being killed when pursuing peaceful legal voyages because the Germans were doing their utmost to starve us out, and sank all ships at sight, regardless of nationality. The result was that the American nation came into the struggle with very serious results to Germany.

THE INSTITUTION OF MECHANICAL ENGINEERS.

The annual general meeting of the Institution of Mechanical Engineers was held in the rooms of the Institution of Civil Engineers, Great George-street, Westminster, S.W., on Friday evening last, the 21st inst., Mr. Michael Longridge, president, in the chair. The usual formal matters have been dealt with, the president said the next business on the agenda was to read and consider the annual report of the council, but, as the report had been circulated to every member of the Institution, and as there was a good deal of business to be done that evening, he did not propose to read it. Before, however, moving that the report be adopted, he would like any member who wished to make any remarks upon it to do so.

As apparently no member desired to make any remarks on the report, the president said that he wished to do so himself. The members would find in the report a paragraph which had never appeared before, relating to "members in India." As many of the members had probably not read the report, he thought the best plan to adopt would be for him to read that single paragraph, which was as follows: "Since the first meeting of the Calcutta section of the institution in 1908, the position of our members in India has been the subject of frequent communications with the institution. In the summer of 1917 a letter was received from the chairman of the section enclosing copies of letters which had passed between himself and other influential members resident in India making definite suggestions for the foundation of an Indian branch of the institution, with a lecture hall, reading room, permanent secretary, and clerical staff. For financial and other reasons the council were unable to support the scheme proposed, but were of opinion that the disabilities under which members resident in India (and in other parts of the British Empire) lay might be removed to a large extent by the formation of associations of local sections of the Institutions of Civil, Mechanical,

and Electrical Engineers (and possibly some other engineering institutions) for the purpose of maintaining meeting rooms and technical libraries in places where sufficient local support existed. In this way it was thought the financial burden upon each institution could be lightened, and the interest in the local meetings increased by the greater number and variety of the papers offered for reading and discussion. The possibility of co-operation for this purpose was discussed at a meeting of representatives of the councils of the three institutions in January, 1918. Unfortunately the Institution of Civil Engineers was unable at the time to see its way to common action. On the other hand, the Institution of Electrical Engineers regarded the proposal favourably and expressed willingness to co-operate with this institution; and the councils have therefore laid before their members in India suggestions for the formation of the suggested associations, and have invited criticism with a view to the evolution of a definite scheme suitable to that country." While those negotiations were going on, the Industrial Commission in India raised a project of an Indian Institution of Engineers, and that project seemed so likely of realisation from what could be heard that the council added the further proposal to those he had already read out: "The council have also expressed their willingness, should the members resident in India so desire, to consider an alternative proposal which they are aware is under discussion in India for the establishment of an Indian Institution of Engineering, incorporated by charter or otherwise, so as to form a corporate body of the members of the Institutions of Mechanical and Electrical Engineers in India, in close association with and affiliated to the home institutions, and receiving their financial support. The council, however, consider that full membership of such an institution, *i.e.*, membership with full privileges and voting power, should be dependent on membership of one of the home institutions, though not thereby precluding admission to other grades of membership with limited privileges, such as associate and graduate, subject to qualifications similar to those now required by the home institutions. These proposals are now under consideration in India, and the opinions expressed there will receive most careful consideration by the council when they are received." Since the report was printed, there had come into the hands of the council an account of a meeting held on December 30 last in Calcutta, over which Sir Thomas Holland presided. The object of the meeting was to see whether it was possible to form an Indian Institution of Engineers, incorporated by charter, as the Institution of Civil Engineers was in this country, to embrace all classes of engineers; and the meeting passed a resolution appointing a committee to consider the following points: (*a*) Steps to be taken, with a view to co-operation, to approach the representatives of the provincial engineering congresses, the Mining and Geological Institute and the local branches of the English Institutions of Engineers; (*b*) to suggest a name and provisional constitution for the new society; (*c*) to nominate a list of provisional committee with a view to completing negotiations with the related congresses and societies; (*d*) to provide means for provisional finance; (*e*) to propose a date and arrangements for an inaugural meeting." That committee was to report to a conference on January 3, 1919. What the result of the meeting was the council did not know, but they did know that there was every prospect—in fact, he might say almost a certainty—of the project being carried through. Whether it would be a success or not was quite another question, but whether it was or was not a success he thought the policy the institution ought to adopt was to get into touch as soon as possible with the committee which had been appointed to draw up the laws and regulations of the proposed Indian institution, so that they might have some say in the matter. He desired to ask the members in annual meeting assembled to agree to the sending of the following telegram to Sir Thomas Holland, the chairman of the committee: "The annual general meeting of the Institution of Mechanical Engineers congratulate their fellow members in India on the proposal to found an Indian Institution of Engineers and offer co-operation." That telegram did not bind the institution to anything; it was entirely non-committal, but it must draw an answer. It also showed that the institution did not propose to leave its Indian members entirely alone to fight their own battle in India. The council might have sent the suggested telegram, but he thought it would come far better from the annual general meeting of the institution.

On this resolution being put, the meeting unanimously decided that the proposed telegram should be sent.

The president next said there was one other unusual subject dealt with in the report, namely, "Patent Law Amendment." As many of the members no doubt knew, a Bill was drafted early in the year, and the institution asked the Board of Trade to allow them to examine it with a view to making amendments. When the Bill was received the council of the institution appointed a committee to examine it, and it was then found that while it contained some very good points, there were others that required alteration or omission. The council learned also that a number of other societies were considering the Bill, and they therefore thought the best course to adopt would be to call a conference of all the societies concerned, which he did. The matter was discussed, and while, of course, the conference did not agree on matters of detail, it came to several general conclusions. The Board of Trade was asked to receive a deputation; it agreed to do so, and the case was laid before that Government department. The headings of the case were given in the annual report. He did not desire to say anything further on the report, and would conclude his remarks by moving "That the annual report be received and adopted."

Mr. Percy L. Young said that now the war was drawing to a close, and the institution was likely to regain possession of its house, he ventured to ask the new council kindly to consider the desirability of increasing the usefulness of the institution by extending the facilities for social intercourse among the members. With that object in view he desired to make the following suggestions:—(1) That the house be closed later than 5.30 on a regular night of the week throughout the session; (2) that when the council had no fixture, informal meetings be held for the conversational discussion of topical subjects under free and easy conditions. Many discoveries had been made during the war, information of which might be imparted in the course of personal reminiscences; (3) that a House Committee having initiative and resource be appointed by the council to ensure the success of those evenings. The growth in London of so many societies reading mechanical engineering papers would probably be checked were those extra facilities available at the Institution of Mechanical Engineers.

The president gathered that Mr. Young did not move a resolution to carry into effect his proposals; in fact, it would be impossible for the meeting to pass such a resolution, because there were so many considerations involved. There was a very great deal, however, in what Mr. Young had said, and he promised that the matter would receive the serious consideration of the council. Would that meet Mr. Young's wishes? [Mr. Young replied in the affirmative.] The president pointed out that there was no hurry about the matter that Mr. Young had raised, because, unfortunately, there was no certainty at the present time as to when the institution would regain possession of its house. There was one other matter he desired to bring before the notice of the meeting, namely, the time at which the meetings were held. A letter had been received from a member asking that the hour of the meetings should be fixed at 8 o'clock, as it was before the war. As a guide to the council he would very much like to obtain the feeling of the meeting in regard to the desirability of continuing to hold the meetings at the present hour, 6 o'clock, or whether it would be desirable to revert to the pre-war custom of holding the meetings at 8 o'clock.

The question was then put to the meeting, when about 67 members voted in favour of continuing to hold the meetings at 6 o'clock and a very much smaller number voted for holding the meetings at 8 o'clock.

After a short discussion, in the course of which the question of adopting other times of meeting than 6 p.m. or 8 p.m. was raised by Mr. Reginald Marshall and Mr. A. P. Trotter, the president stated that he had simply taken a show of hands in order to give the council a guide as to whether they should take the matter into consideration at all. If the council found there was really a desire for an alteration in the hour of the meetings when the train service became a little better, he thought the best plan would be to send out a voting paper to the London members and to abide by the wish of the majority.

Mr. John Heatherington then formally seconded the motion for the adoption of the report, which was put and carried unanimously.

The president then presented the various premiums and prizes that had been awarded during the past year. The Willans Premium was presented to Messrs. F. H. Trevithick and P. J. Cowan for their paper on "Some Effects of Superheating and Feed-Water Heating on Locomotive Working." The Water Arbitration Prize was presented to Mr. A. E. L. Chorlton, C.B.E., for his paper on "Notes on the Construction of Turbine Pumps." The Thomas Hawksley Gold Medal for 1919 was awarded to Mr. L. A. Legros, O.B.E., for his paper on "Traction on Bad Roads or Land."

The president presented Mr. Legros with a bronze replica of the Thomas Hawksley Gold Medal, stating that at the present time it was impossible, owing to the war, to get a gold medal made, but as soon as it was possible to do so a gold medal would be struck and sent to Mr. Legros. The Thomas Hawksley Premium of £10 was awarded to Professor C. A. Edwards and Mr. F. W. Willis for their paper on "A Law Governing the Resistance to Penetration of Metals when Tested by Impact with a 10 mm. steel ball; and a New Hardness Scale in Energy Units." The prizes for the most successful students in the institution examinations were awarded to Mr. L. C. Leigh, who obtained 73 per cent. of marks in the examination paper for the associate membership examination, and to Mr. G. H. White for the graduates' examination.

The president said the time had now arrived when he must retire from the great position to which the members elected him two years ago. It was an act of self-abnegation which every president had to perform, but it was usually accompanied by the compensation that he formally introduced the new president to the members and placed him in the presidential chair. Unfortunately he had not that pleasure on the present occasion, because he received a letter just previous to the meeting from Dr. Hopkinson, in which he stated: "It is absolutely useless to attempt going out to-night; I have had to send for the doctor instead. Please make my apologies to the members." Dr. Hopkinson had been suffering from bronchitis. Contrary to the advice of his doctor he came to London specially in order to attend the meeting. He (the president) saw Dr. Hopkinson that morning; he was in bed, but said that if it were in any way possible he would get up and attend the meeting at 6 o'clock. Unfortunately he got worse during the day and had to send for the doctor, who had absolutely forbidden him to come out, so that he had not the pleasure of inducting him into the chair. But he thought he might say a few words which he would have said if Dr. Hopkinson had been present. He desired to say that in electing Dr. Hopkinson as president he thought the institution had chosen well, and he was quite confident the honour which had been conferred upon Dr. Hopkinson would be reflected back upon the institution. Dr. Hopkinson bore a name which was known and honoured by engineers throughout the world. He represented alike the science and the art of the mechanical engineer, for he was a doctor of science on the one hand and, on the other, he stood at the head of a great manufacturing concern. To his ability as an organiser and a man of science the reputation of his firm bore witness, while his high character as a man and as an employer of labour was attested by the fact that the

working-class constituency in which his works were situated had sent him as their representative to Parliament. He (the president) did not think he need say more to justify the nomination of the council or the election the members had made. He desired to ask that he might be allowed to send Dr. Hopkinson a message from the meeting expressing their regret that he could not be with them and at the cause of his absence, and the hope that he might be able to take the chair at the next meeting. The only other business that remained for him to transact before he retired was to ask the secretary to declare the election of the officers.

The secretary announced that the ballot lists for the election of officers had been opened by a committee of the council that afternoon, and the following were found to be duly elected: As president, Edward Hopkinson, D.Sc., M.P.; as vice-presidents, Henry Davey, Mark H. Robinson; as members of council, Professor W. E. Dalby, F.R.S.; John Dewrance; William H. Patchell; G. R. Sharpley; William Taylor, O.B.E.; the Right Hon. Lord Weir, P.C.; Wilson Worsdell.

The president said the only thing that now remained for him to do was to leave the chair, and in Dr. Hopkinson's absence to ask Mr. Henry Davey, the senior vice-president, to take it, in accordance with paragraph 19 of the Articles of Association. The chair was then vacated by Mr. Michael Longridge and taken by Mr. Henry Davey, the senior vice-president. The chairman (Mr. Henry Davey) said he took the chair not with pleasure but with great regret, owing to the fact that the president-elect, Dr. Hopkinson, was not able to be present on account of his serious illness. He filled the president's place as an act of duty, and his first duty was to call on Dr. Maw to move a resolution.

Dr. W. H. Maw said that, as the senior past-president attending the meeting, it was again his privilege to ask the members to accord a most hearty vote of thanks to the retiring president for the admirable way in which he had discharged the duties of his office during the past two years. During those two years special duties had been thrown upon the President, because, in addition to the ordinary work of attending and conducting the meetings of the Institution, he had been concerned with the carrying out of the work of a number of special committees. Extra work had had to be done in connection with the Patents Amendment Act, the arrangements for promoting the interests of their fellow members in India, and a number of committees in connection with the Ministry of Munitions, on which the president had taken a most active part. The amount of time the president had devoted to the work of the Institution was only known to those who had been intimately associated with him during the past two years. In fact, during all the time that he (Dr. Maw) had been associated with the Institution he had never known the demands upon the president to be so heavy. In the course of his remarks Dr. Maw stated that there was one point which he desired particularly to mention, namely, that all members were deeply indebted to the retiring president for the memorable address he delivered in that hall two years ago. During the past half-century it had been his fortune to be present at the delivery of some dozens of presidential addresses, but he could not call to mind a single occasion when such an address met with anything approaching the enthusiasm aroused by Mr. Longridge's discourse. The address was one of an entirely exceptional character, and it was not difficult, he thought, to realise why it aroused such enthusiasm as it did. It was an address that appealed to the members not only as engineers but as men. When he heard it he was irresistibly reminded of that noble poem of Longfellow's, "A Psalm of Life," because the spirit which animated Mr. Longridge's address and the spirit that animated that poem were identical. They were both exhortations to bring about a better state of things and in every way to make the world, as far as they could, better than it used to be. It was unnecessary for him to say any more, and he therefore would at once ask them to accord a most hearty vote of thanks to Mr. Longridge for the manner in which he had performed his duties during the past 2 years.

Dr. W. C. Unwin said it was an honour to have been asked to second the resolution, and it did not require many words from him to do so after the remarks Dr. Maw had made respecting the work of the president during the past two years. They had been years of difficulty, but he thought it might be said that in no material respect had the Institution suffered from the restrictions which had been imposed upon the country, and it was due to the energy and to the care with which the work of the Institution had been conducted by the President that that had come about. He had very much pleasure in seconding the resolution.

The chairman said that in view of the eloquent remarks by Dr. Maw and Dr. Unwin he would not detain the members by attempting to make a speech, and he could not do better than say that he endorsed every word that had been said by them. Personally, he desired to express his great appreciation of Mr. Longridge's character and abilities, and he assured the members that the work which Mr. Longridge had done in the interests of the Institution during his term of office was something that could only be realised by the members of the council. The resolution was then put and carried with acclamation.

Mr. Michael Longridge, in reply, said he thought few men could be so unsympathetic and so stony-hearted as to listen unresponsive and unmoved to the speeches which had been delivered, and he certainly was not one of the few. The speeches that had just been made were a welcome crown to his two years of office as president of the Institution, and they were the more welcome owing to the way in which the members had received them, because he gathered, from the cordial reception that had been given to them, that the members believed he had done the best he could. There was some little ground for dissatisfaction in what had been said, and there was a blank which he would ask leave to make good. The guidance of the Institution depended far more upon the council than upon the president. The council had 30 votes in any matter that came up for decision, while the president had only one, and it was to the ripe experience, the wise advice and the loyal support of the council, the vice-presidents, the past-presidents, and to the unobtrusive labour of Mr. Worthington and his staff, that a large proportion of the praise which was unfairly showered upon the president on such occasions as the present was due. He desired to thank Mr. Worthington and his staff for their courtesy and forbearance; he desired to thank the Council for their loyal support, and he desired to thank all the members for the kindly way they had always received him. They had made his occupation of the chair a pleasure and they had made his leaving it a regret.

The proposal for the reappointment of Mr. Raymond Crane, F.C.A., as auditor of the accounts of the Institution for the present year having been proposed by Professor D. A. Low, and seconded by Mr. Douglas T. Heap, was then put to the meeting and carried unanimously, and the chairman then announced that this concluded the business part of the meeting, and that the discussion on the four papers, on "Electric and Acetylene Welding," which was commenced at the last meeting,* would next be continued:—

ELECTRIC AND ACETYLENE WELDING.

Mr. S. G. Martlew, in opening the discussion, said that conscientiousness and sound judgment, combined with wide knowledge of metals, were absolute essentials of the all-round operator. His safety and that of persons in his proximity should be provided for. Dark mica cut off heat rays very effectively, but its opacity obscured the vision, so that the eyes were better guarded by combinations of glass capable of nullifying injurious emissions. In the case of gas-welding, that might be a greenish-amber tint, but, for the more potent rays of the electric-arc, the ultra-violet were absorbed by dark green, the infra-red by deep ruby, and the shield would be completed with smoked lead, protected by plain. Those four layers of glass were arranged in the order named, counting from the worker's eyes. The skin of the operator and of those near to extensive welding jobs should be thickly covered with heat-and-current-resisting material, such as stout waterproof leather; an aluminium helmet was often employed, and left both gauntleted hands free. The object to be welded should always be earthed, thus lessening the chances of shock, for even slight discharges had been the cause of accidents when work was being done on a staging or other risky situation. In the welding of vessels subject to pressure and heat changes, his experience, covering both gas and electric processes, inclined him to favour the latter. As an instance, he referred to a fractured steel valve body for superheated steam. Every time that such was oxy-acetylene welded, subsequent pressure-tests disclosed oozing, but soundness was finally attained by employing the electric arc. More recently he had a defective superheater-header, ¾ in. thick, successfully treated with Low Moor iron pencils bearing a direct current of 450 amperes and 175 volts. After passing a hydraulic test to 255 lb. per sq. in., that had for months been under a daily working pressure of 170 lb. per sq. in. Remarkable results with somewhat similar apparatus

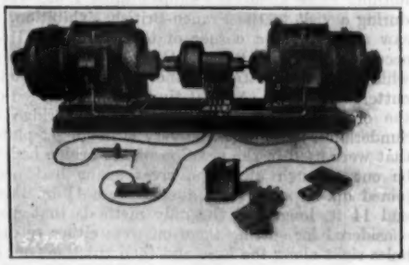
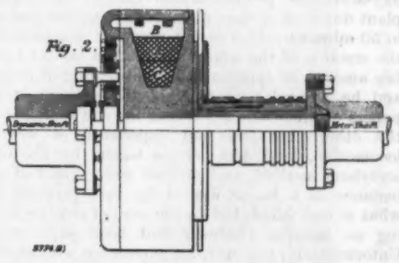


FIG. 1.



were reported from Canada, in the shape of repairs to furnace-tube cracks, which were actually accomplished while the boiler was carrying 125 lb. per sq. in. steam pressure. By careful working of the electrode, a thin skin was first laid over the leak, and, the water thus being stopped, the weld was built up in the ordinary way. He invited the attention of the members to a couple of slides lent by the courtesy of Messrs. the Equipment and Engineering Company, London, illustrating their plant which he had tried during the present week. On the right of Fig. 1 was the motor or source of power driving the direct-current dynamo on the left through the magnetic clutch seen in the centre. Details of the latter were shown in Fig. 2, wherein A was a steady-potential coil from constant-voltage supply, such as the motor; B was a dynamo-series-coil, resisting A, and C was a shunt-coil across the dynamo-terminals, also opposing A. He found that the clutch gradually slipped when regulation of current was needed; for example, if the welding rod or the cutting carbon actually touched the work the dynamo slowed up; also, by listening to the running of the machine, it was distinguishable whether he was keeping the electrode the right distance away. That clutch economically took the place of the usual series-resistance and offered a solution of driving problems not wholly restricted to welding.

Mr. W. H. Patchell asked what volts were used across the arc; 175 seemed to be rather high, and the statement had been made that the clutch took

* See ENGINEERING, page 148 *ante*.

the place of the ordinary series resistance. In reply, Mr. Martlew stated that the machine illustrated in the figures he had shown was not used for the welding job he described in the earlier portion of his remarks; a different machine was used in that case. The one to which he made reference when showing Figs. 1 and 2 had only 35 volts across the terminals when he used it during the present week.

Mr. R. C. Macdonald said that when, in the winter of 1902-03, Professor Vivian Lewis delivered a lecture to the Royal Society of Arts on the subject of acetylene welding, he was connected with a firm of tube manufacturers that manufactured its tubes by lap-welding, and it was very often found that in otherwise good tubes there was a short portion of the lap that did not weld on passing through the rolls. It struck him that acetylene welding would be a very good method of recovering those otherwise good tubes. He wrote at the time to the firm mentioned in Professor Vivian Lewis's lecture, and was informed by them that the tool was hardly ready to come on the market, but they promised to let him know as soon as it was available. He heard nothing more about the subject until 1909, when, during a visit to the Franco-British Exhibition, he saw a stand, in a corner of the Machinery Hall, occupied by the British Oxygen Company, at which a demonstration of the working of a metal cutter was given. At that time he was engaged on the erection of the Queen Alexandra bridge at Sunderland, in which some very large gusset plates that were used in the erection of the bridge had to be cut through after the river spans had been joined up. Some of the gussets were 1½ in. thick and 14 ft. long, and the only methods that were considered for cutting them off were either to drill holes right along the base and then cut them off, or to use a pneumatic chipper to cut them off. Previous to his visit to the exhibition he had cut one of them with a pneumatic chisel, and it took three days to do the work. He got in touch with the oxy-acetylene people in Newcastle who sent a plant down on to the job, and they cut the first one in 50 minutes, which meant a saving of a month in the erection of the work. Since then he had had a fair amount of experience in the welding of boilers, and he noticed that none of the authors of the papers claimed any advantage for one system over the other. He had had experience of welding locomotive, land and marine boilers by the oxy-acetylene method, and he had never yet had one instance of a boiler welded by that process, but what it had failed, but in the case of electric welding no failures whatever had been experienced. Unfortunately, however, his experience with electric welding was not so great. Owing to war restrictions, his firm could not get permission to obtain a new boiler to replace a very old boiler in a ship in which both the furnaces were leaking very badly. It was necessary, however, to keep the ship going, and in order to do so the boiler was welded by the oxy-acetylene process and it lasted for about three months, when trouble again occurred. He felt very much inclined to do nothing further with welding but to attempt to patch the boiler up. However, he was prevailed upon to try electric welding, and it turned out to be a wonderful success. The metal was built up, and until the Germans put a torpedo into the ship the boiler stood up well. Since then he had carried out a good many repairs on cracked steel fire-boxes in locomotives and marine and land boilers, and in every case they were holding up well. One subject upon which he desired to obtain further information was the welding of copper, which had been mentioned by previous speakers. He had frequently tried to weld the cracks in copper fire-boxes but had not been successful in doing so. In view of the difficulty that had been experienced during the war in obtaining copper, it had been most essential that an endeavour should be made to do something of that sort, and if copper fire-boxes could be welded it would be an improvement onthe old method of filling up cracks in them.

Sir Henry Fowler, K.B.E., desired to press home the point that had been made by the previous speaker that it was not so much a question of the welding of the copper as the building up of the copper plate. If that could be done with the locomotive fire-boxes, a very great advance would be made. He did not quite see how it could be done, because the trouble which had been experienced in experimental work was that, owing to the high conductivity of the copper, the heat got away too rapidly. He would be very glad indeed if the author, who referred to the building up as a feasible process, would explain exactly how he did it. With regard to the question of locomotive fire-boxes, he knew, from what he saw in the States a little time ago, that the internal fire-boxes were welded with oxy-acetylene, and they had run perfectly satisfactorily for a considerable time.

A member enquired whether Sir Henry Fowler was referring to a steel fire-box. Sir Henry Fowler replied that he was referring to either steel or iron; they were mild steel boxes in the particular case he saw. Acetylene welding was used in a connection which had not been sufficiently considered, namely, in the way of repairs and building up. For instance, if the end of a piston rod wore, the Americans built fresh stuff up on the cone and then turned it down. He thought that method would have been more extensively used in this country on electrical work had it not been for the very great success which had attended the electric deposition of steel on to worn parts of aeronautical engines. He desired to ask whether the authors had had any experience of a rod in which the outer casing was nickel. His own experience with such a rod showed that it was not a very great advantage, but it was claimed that some people obtained a considerable advantage by using that type of pencil. A point that had not been raised in connection with aeronautical work, not in connection with the engines but in connection with the planes, but which had received considerable attention during the war, was the welding of aluminium. At the beginning of the war that was a matter of considerable difficulty, but a suitable flux had now been found. The Engineering Standards Committee had standardised the flux for that work, with the result that very beautiful and complicated sections could now be obtained by means of oxy-acetylene welding of aluminium, which could afterwards be beaten and treated as if it was an ordinary plate. One new incidental method of using oxy-acetylene flame on tubes was in connection with the experience of a certain railway company, which found that very considerable pitting, through the use of peaty water, occurred. By taking the tubes out they were able to weld the pit-holes up and use the tubes over again.

Mr. Daniel Adamson said that one difference between the electric and the oxy-acetylene welding processes was that with the former the use of the metallic arc was more readily learned by unskilled workmen than with the oxy-acetylene process. Another difference was that the electric arc welding was more local in its effect, and the same troubles were therefore not obtained, due to the expansion of the parts being welded together, as would be the case with the acetylene flame. That caused difficulties in contraction afterwards, if not provided for, and in that respect the electric process, being more local, was more easily brought to a satisfactory conclusion. He believed the electric metallic arc was more suitable for thicker plates than acetylene welding. Some illustrations were given, in Mr. Heaton's paper, of the Kjellberg process, and it would be of interest to the members, if the author could state how the particular difficulty he mentioned of allowing for the expansion resulting from the operation of welding was provided for in such cases as there illustrated, where the boiler was a complete structure and the welding had to be inserted within the structure at the parts that required repair, with no doubt considerable heating effects at those points. The question of testing the welds, which had been mentioned in some of the papers, was a very important part of the subject. Tensile and bending tests could be applied to samples, but unfortunately they were tests to destruction, and the weld tested was then of no further use for its purpose. It was to be hoped that some method by means of which inspectors could judge whether the weld had been properly carried out or not would be instituted. At the present time the operator himself knew, if he had had sufficient experience, whether he was making a good weld or not, but there was a fear that he might cover up bad workmanship, and the result would not be evident until it was too late to be remedied. The question of the voltage of the supply current for electric welding had been referred to, but no very clear guidance had been given as to what was really necessary; 25 or 30 volts appeared to be sufficient at the arc itself, but higher voltages were recommended, even 110 volts, which meant a considerable loss of power in the regulation resistance. Would, for instance, 60 volts at the generator be sufficient for the purpose? Then the question arose of alternating current as against direct current. Alternating current if suitable for welding lent itself admirably to reduction in voltage by means of stationary transformers and so avoided the necessity of revolving transformers or converters such as had been illustrated in the course of the discussion. It would also be of value if the authors could give information as to the probable speed at which welding could be carried out on plates, say, from ¼ in. to 1 in. thick, and if the process referred to was the electric process further information as to the amount of electric power used and also the size and quantity of the particular electrode. Information as to the amount of oxygen and carbide used on similar work for the oxy-acetylene process would also be of value. The question of the generation of the necessary amount of oxygen was of considerable importance to prospective users of the oxy-acetylene process. Electrolytic generation, one method suggested in the papers, appeared to be very expensive in electric power, and also in original capital outlay. He took it that most of the systems of welding referred to butted joints as against the ordinary lap joint of riveting or of the old-fashioned fire-welding. A butt-weld did not appeal to him as a reliable form unless its weaknesses could be overcome by a thickening up on both sides of the joints, *i.e.*, the material added was not so strong as the original material and the weakness of the structure was concentrated and localised at the welded joint, with resulting trouble if there was any bending action in the structure due to its working or due to expansion if it was in part of a steam boiler, for example. A lap joint might possibly be better in that respect, if not exposed to fire on the one side where the overlap would be certain to be burned away. It was so very easy to weld by any of the processes, by the metallic electrode or by the oxy-acetylene process, that he feared there was a very great temptation to use a welding process for difficult pieces of structure that could not conveniently be done by other methods, with the result that the joint was put in a very awkward position and no work such as hammering or forging could be applied to the seam, in order to toughen it, similar to the forging or rolling operation which steel was ordinarily submitted to. For example, great care was taken in the manufacture of steel plates that the material should be of very reliable quality. That gave rise to a considerable amount of hesitation to make use of the ordinary mild steel boiler-plate of commerce and apply to it a process of joining which, from the very nature of it, was not nearly so reliable as the original material.

Mr. F. C. Hibbert said the recent developments in welding had awakened widespread interest amongst the engineers of the world. Doubtless many searchers after wisdom would hope that, as a result of the reading and discussion of no less than four papers on the subject by members of the Institution, they would be able to come to some conclusion as to the respective merits of the various systems. A casual glance at the papers in question would perhap lead to the inference that, whereas three experts favoured the autogenous system, only one could be found to discuss seriously the merits of electric welding, and, from the opening remarks of Mr. Heaton's paper, one could only gather that even he was not prepared to advocate the advantages of the latter. It was probable, however, that the consensus of opinion of welding experts at the moment might be aptly summed up in Mr. Heaton's words, "Each known system of welding has its proper sphere." But it would appear that the possibilities of future development in welding were

TYPICAL SUBMARINE BOATS OF THE BRITISH NAVY.

CONSTRUCTED BY MESSRS. VICKERS, LIMITED, NAVAL CONSTRUCTION WORKS, BARROW-IN-FURNESS.

(*For Description, see Page* 264.)

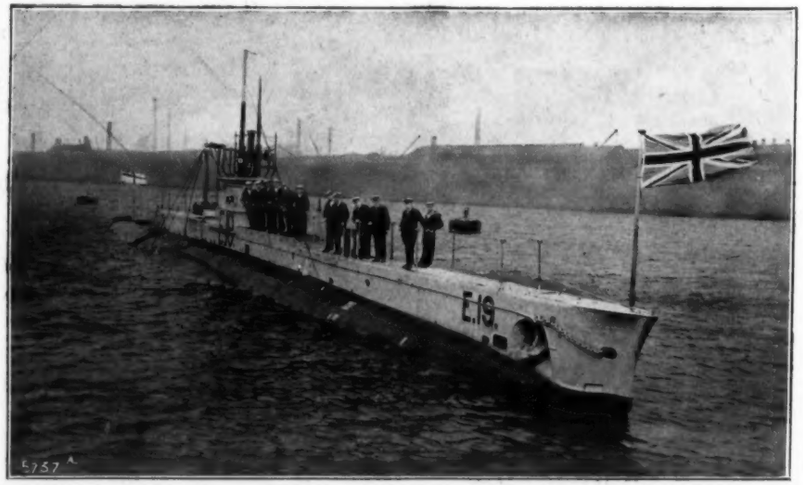


FIG. 1. THE "E" CLASS.

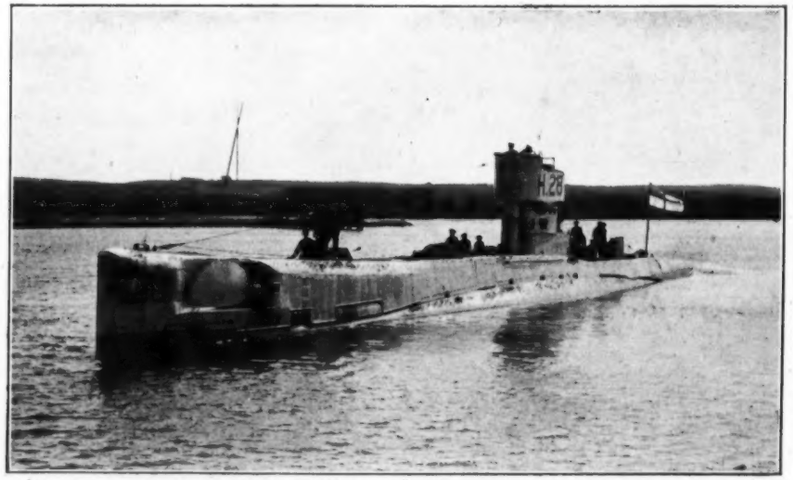


FIG. 2. THE "H" CLASS.

FIG. 3. THE "G" CLASS, WITH COMPLETE DOUBLE HULL.

(*To face page* 264.)

TYPICAL SUBMARINE BOATS OF THE BRITISH NAVY.

CONSTRUCTED BY MESSRS. VICKERS, LIMITED, NAVAL CONSTRUCTION WORKS, BARROW-IN-FURNESS.

(*For Description, see Page* 264.)

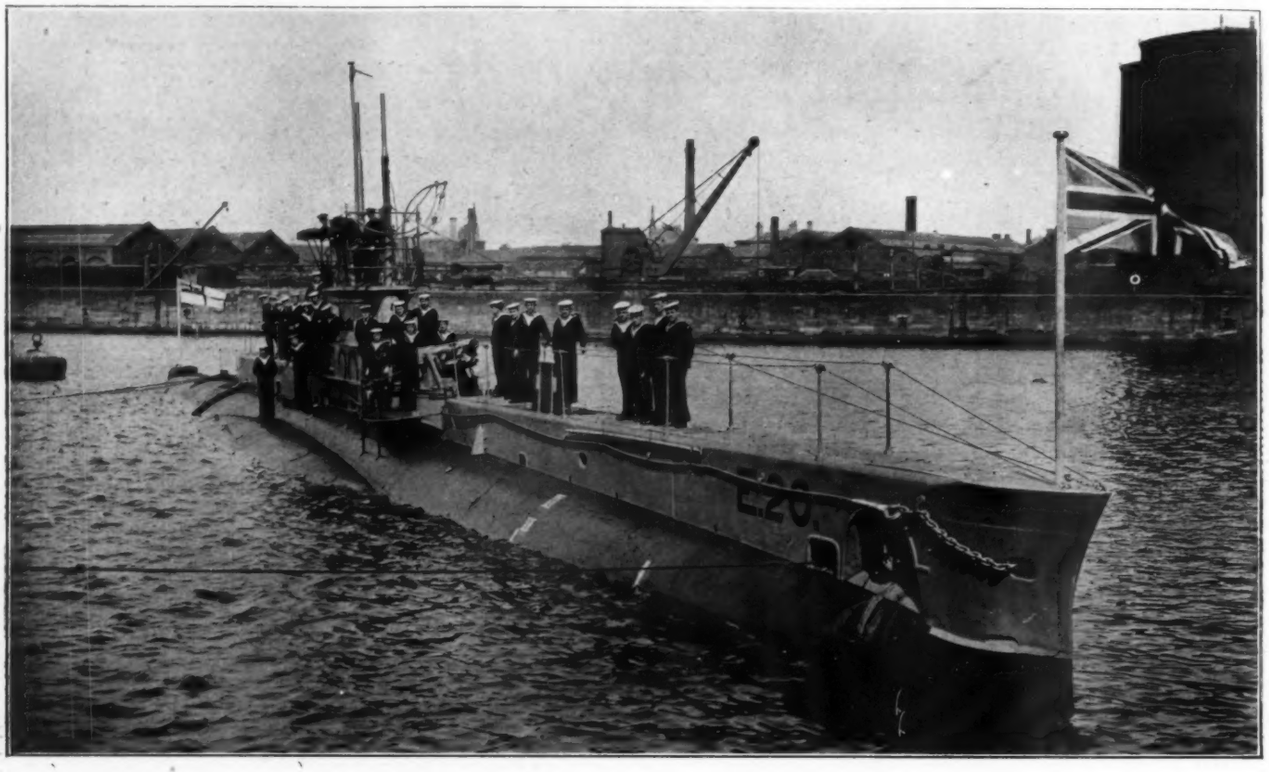


FIG. 4. AN "E" BOAT FULLY MANNED.

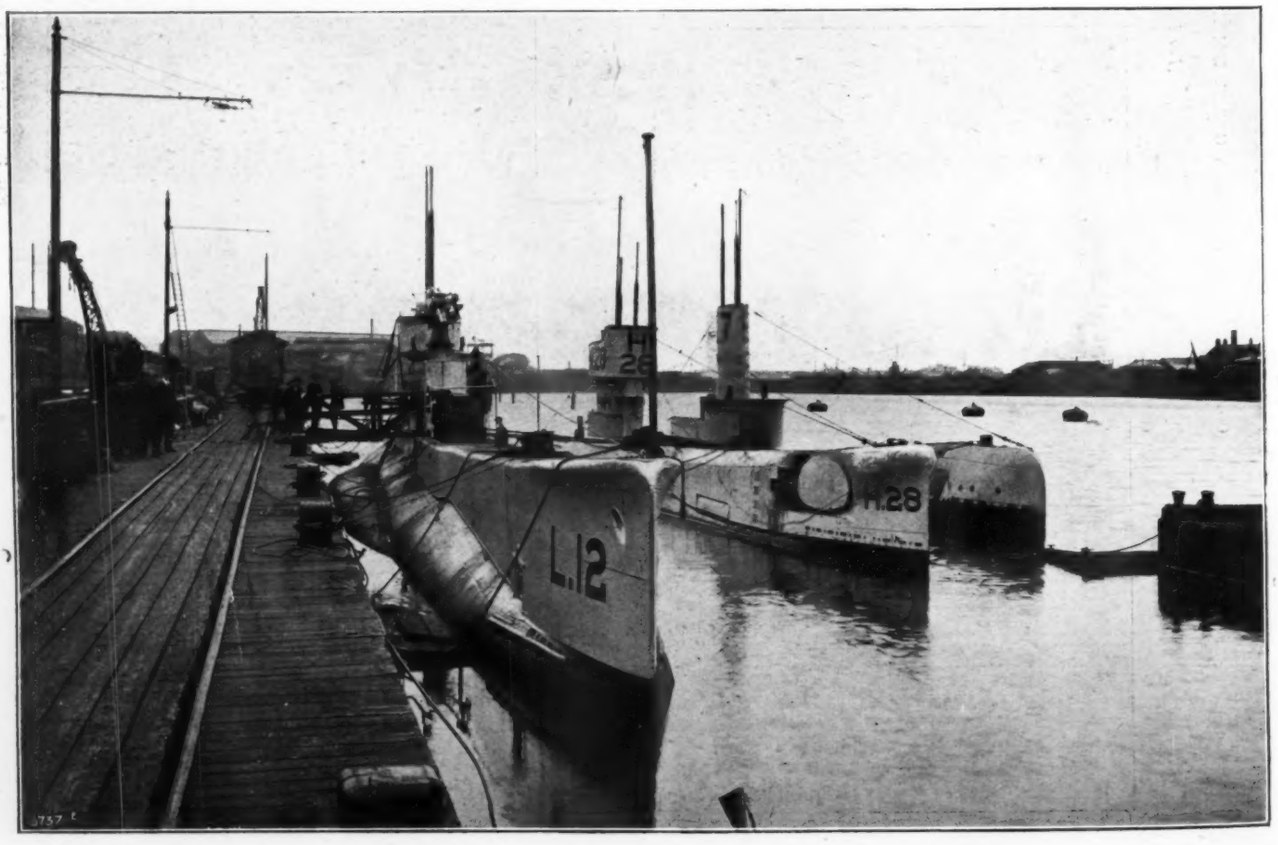


FIG. 5. THREE BOATS DELIVERED ON ONE DAY.

TYPICAL SUBMARINE BOATS OF THE BRITISH NAVY.

CONSTRUCTED BY MESSRS. VICKERS, LIMITED, NAVAL CONSTRUCTION WORKS, BARROW-IN-FURNESS.

(*For Description, see Page* 264.)

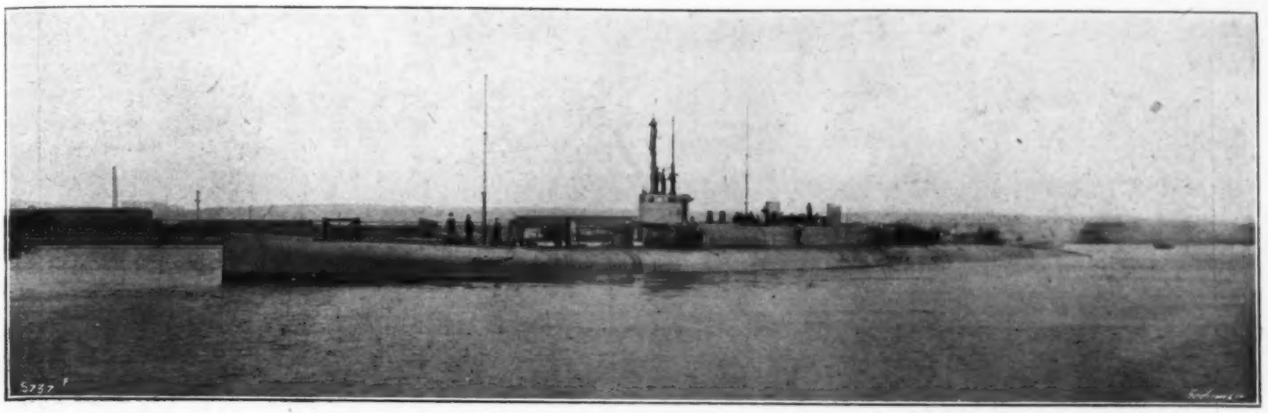


FIG. 6. THE "K" CLASS, PROPELLED BY STEAM TURBINES.

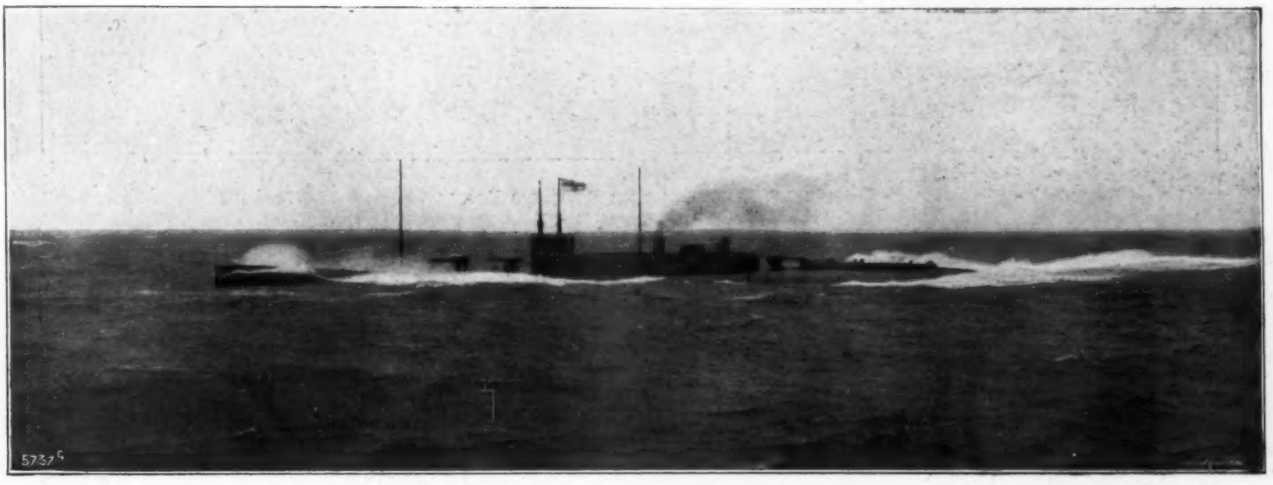


FIG. 7. ONE OF THE "K" CLASS STEAMING AT FULL SPEED.

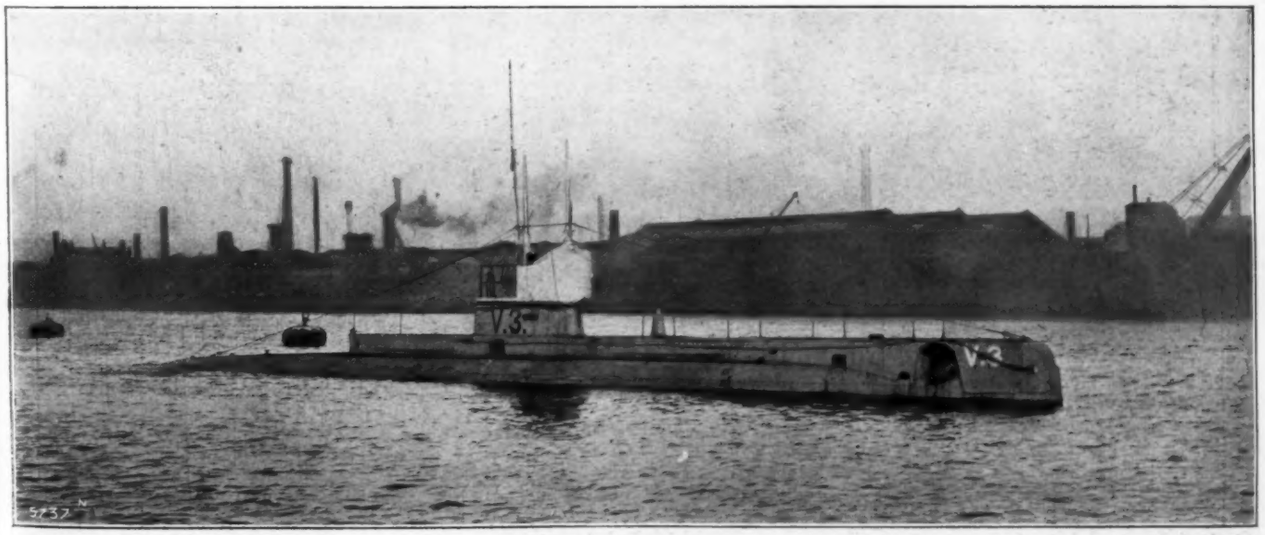


FIG. 8. THE "V" CLASS.

OIL ENGINES FOR BRITISH SUBMARINE BOATS.

CONSTRUCTED BY MESSRS. VICKERS, LIMITED, BARROW-IN-FURNESS.

(*For Description, see Page* 264.)

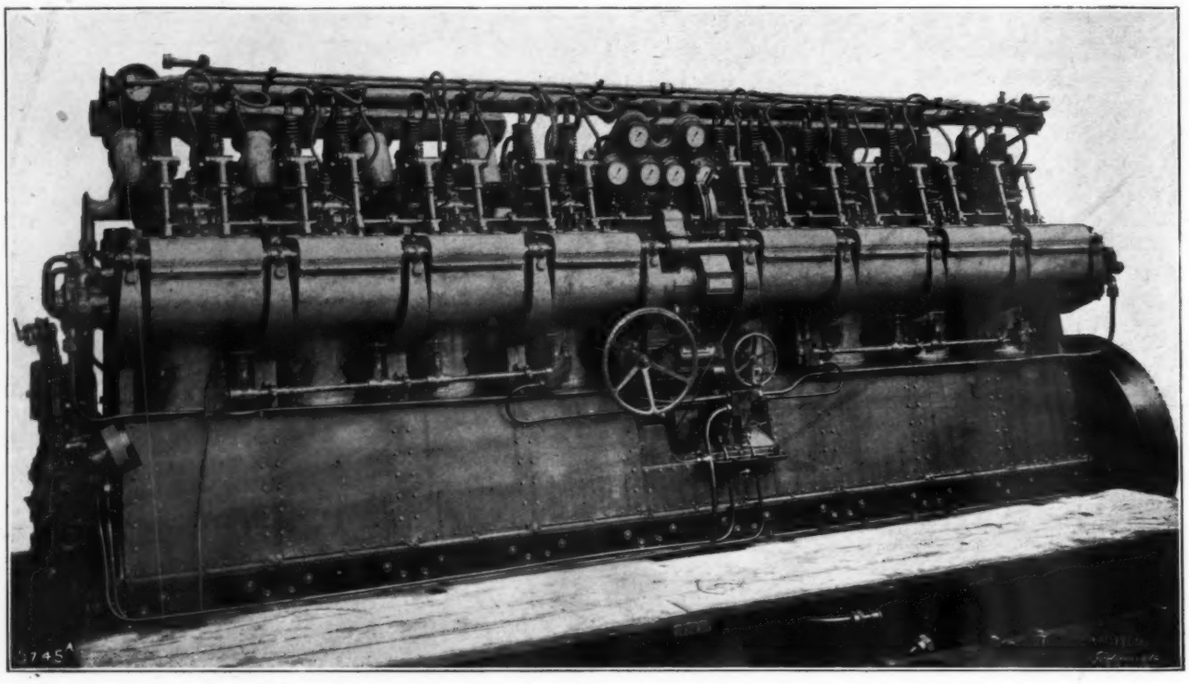


FIG. 9. EIGHT-CYLINDER REVERSING ENGINE.

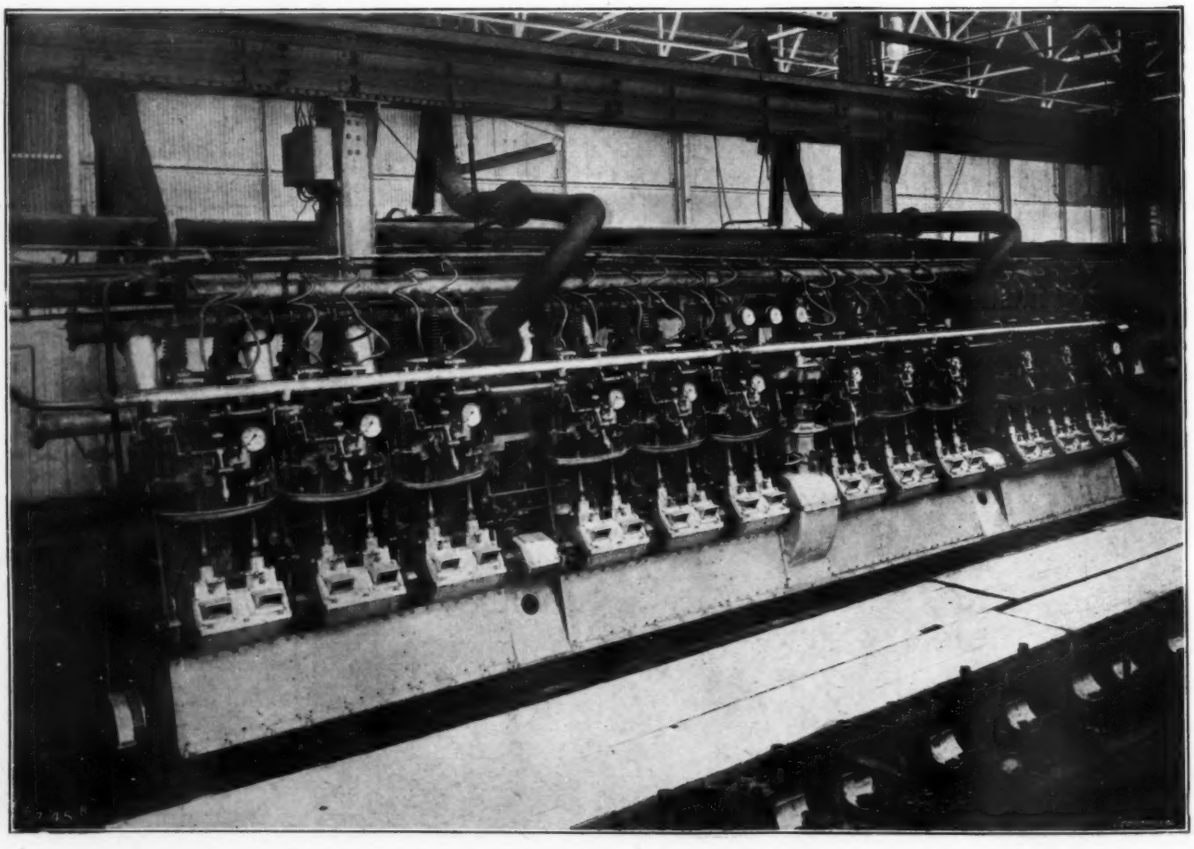


FIG. 10. TWELVE-CYLINDER NON-REVERSING ENGINE.

(*To face page* 265.)

far greater with electric welding—the field for invention for which was still to a great extent unexplored—than with autogenous welding, the improvements in which might be said to be confined to refinements in the blow-pipe resulting in (*a*) reduced consumption of gas and corresponding economy in operation, and (*b*) improved regulation of flame, resulting in better work and the elimination of burns, slag spots, globules and voids. Apart from that, the success and possibilities of autogenous welding would always depend entirely upon the skill of the operator. In the United States the subject of welding had been considered with great interest and a great deal of work, experimental and practical, had been done. Mr. Heaton made the following statement in his paper: "The author understands that in America the Slavinoff process has been used with considerable success, notably in the repairs to the cylinders, &c., of the engines of the German ships Vaterland and others that were requisitioned by the United States Government." There would appear to be some misunderstanding in that connection, because he had reason to believe that the system used was that of Mr. D. H. Wilson. The facts were that in 1917, under circumstances known to all, the United States Government acquired over 100 vessels which had previously been German. Upon examination it was found that the engines had been wrecked and the boilers, pipe lines, &c., wilfully broken; even the c.s. steam chests, core-rods, &c., were fractured, and it appeared that it would be many months, if not years, before the vessels would be seaworthy, and this could only be attained at very great expense. In a few weeks, however, the whole of the repairs were executed by the Wilson electric welding process, and the inventor was called to Washington and warmly complimented by the President. No single case of failure of any of those welds had been reported yet. One of the boats in question was the U.S.S. Leviathan (56,000 tons, 70,000 h.p.), formerly known as the Vaterland. The Wilson welder was originally developed by one of the principal American railroads, the officials of which were convinced of the possibilities of electric welding. They found, however, that, whereas the most expert operators secured good results, such faults as slag pockets, caused by aggregation of carbon, and the corresponding weakening of the weld, caused by excessive heat, and globules and voids caused by insufficient heat, were all too common. In that connection it had been shown that there was a critical temperature in welding, and a variation of 15 amperes above or below the required current would cause the above defects. Mr. Wilson set out to produce a machine which could be regulated at any pre-determined heat, and hold that temperature constant to within approximately 6 per cent., and it could not be too strongly urged that it was upon that proper regulation of temperature that the success or failure of all welding depended. Another point of great importance was the composition of the electrodes, which must be such that they were not adversely affected by the heat of the arc. In that connection it should be noted that an excess of manganese, to compensate for the loss in the electric arc, was necessary. Uniformity of composition of the electrodes was essential. Without doubt the possibilities of the use of electric welding were still but imperfectly understood, and much work, experimental and other, remained to be done. In that connection the remarks of Mr. Heaton on the necessity of testing and the field for research in that matter were of the greatest possible interest.

Mr. Thomas T. Heaton, in reply to the discussion on January 24, said that Mr. Kennedy, of the British Arc Welding Company, who opened the discussion, drew attention to illustrations in the paper, Figs. 10, 11 and 12, where the statement was made that the system of welding shown therein was the Kjellberg System. The work illustrated was done by the British Arc Welding Company, Limited, by their system, and Mr. Kennedy stated that the system used, though it included a coated metallic electrode, was different from the Kjellberg system. The same remarks also applied to Fig. 18. While his (the author's) statement was made in perfectly good faith, he of course accepted Mr. Kennedy's contradiction and had taken steps to modify the paper in anticipation of the form in which it would finally appear. Since reading the paper he had received a communication from Mr. J. W. Aitken, of the Anglo-Swedish Electric Welding Company, Limited, which had the sole rights of the Kjellberg system in this country, who desired him to say that the sample welds shown in Fig. 18, plate 5, were not made by the Anglo-Swedish Company. He wished to make it quite clear that Mr. Aitken was unaware that the name Kjellberg was being used in the paper. Also in the text of the paper, it was not correct to say that the slag was dissipated in all cases. There were cases in which slag was deposited, and the slag was arranged to be deposited or not according to circumstances. The welding wire was soft steel, and not soft iron as stated in the paper. The functions of the cover were not fully stated by him, as other functions of an important nature were provided by the cover in order to affect the weld as might be desired. The objection suggested in regard to changing electrodes as they were consumed was by no means important as, in a recent test of five hours duration, the average time taken to change the electrodes was only 5 seconds per change. Mr. Aiton had enquired whether the welds referred to in the paper made in mild steel $\frac{1}{2}$ in. thick were hammered. Welds made in the side of a steel barrel or a tank by the Benardos process were hammered. There was an example, among the specimens exhibited, of a steel sheet with two bosses welded into it. The sheet was only 14 B.G. thick. The bosses welded in by the Benardos process were fused without the addition of any metal, and the welds in that case were not hammered. In reply to the further questions raised by Mr. Aiton he desired to say that carbon arc welding of cast iron had been quite successfully done by himself in simple cases, and there was no reason why it should not be successful if the proper means were used as commonly adopted for cast iron welding. Towards the end of the paper there was a reference to an example of a cast iron fly-wheel being welded successfully by Messrs. Lloyd and Lloyd years ago. Cutting with the carbon arc was quite a commercial success, but he would not recommend it except under special conditions for large thicknesses. The table set forth early in the paper headed "Cutting Mild Steel Plates," dealt with that matter. He quite agreed that shell discard steel was not suitable for welding. Mr. J. H. Newton, in speaking of the welding of high-speed steel cutting edges of tools to shanks made of mild steel, asked whether it was possible to indicate the limits of temperature on which success depended and whether any flux was necessary. He was not able to give definite figures for the temperature, but, as stated in the paper, it appeared to vary for different classes of high-speed steel. A little experience was necessary to enable a workman to judge of the temperature when carrying out the operation of welding, but it was soon acquired by an intelligent man. No flux whatever was required, but it was necessary that the surfaces to be joined should be clean, and within his experience those were generally machined surfaces. The remainder of the discussion on the last occasion appeared to refer to the oxy-acetylene welding, and did not fall within his province to reply to. He would reply in writing to the points that had been raised at the present meeting.

On the motion of the chairman, a hearty vote of thanks was accorded to the authors for their interesting papers, and the meeting terminated.

The Benevolent Fund.

The annual meeting of the Benevolent Fund was subsequently held, presided over by Mr. Michael Longridge. The report of the committee was adopted; Messrs. Hawksley, Longridge, Pendred, Sankey and Chas. Wicksteed were elected to the Committee of Management; and Mr. F. H. Norwood (hon. treasurer); Mr. Edgar Worthington (hon. secretary), and Messrs. Macquinnes and Sidney Sharp (hon. auditors) were unanimously re-elected.

The Royal Aeronautical Society.—The lecture arranged by the Royal Aeronautical Society to be delivered by Captain Thurston, D.Sc., R.A.F., on Wednesday, March 5, will not take place, as Dr. Thurston is unfortunately suffering from a severe attack of influenza.

THE GERMAN MOTOR CAR MARKET.

In the earlier part of the war it was considered likely that the market, after the war, would be flooded with motor lorries for which the military authorities had no further use, and that prices, in consequence, would be forced unduly down. That view caused 20 leading firms in the German motor car industry to form a Field Motor Car Company for the purpose of handling such lorries and their component parts. The unlooked-for outcome of the war has removed the cause for the above apprehension, and there is now no question of a surplus of motor cars or lorries; on the contrary, the number which the Field Motor Car Company are at present handling is comparatively small, more especially as regards motor lorries.

Matters were somewhat different as regards passenger cars. The company, even during the war, are said to have delivered a considerable number of these abroad, mostly foreign-made cars, for which it was difficult to obtain spare parts. The cars were sold at good prices, the expense of warehousing and loss of interest being thus avoided. Now, however, passenger cars also are only available in very limited numbers, and there is, further, the tyre difficulty; it has been necessary, therefore, to confine the sale of smaller cars to such persons who need them in their profession, such as doctors, veterinary surgeons, &c. A similar classification or rationing will also be necessary for motor lorries, and a newly-formed concern, the Power Transport Company, will require a number of the better cars to replace those coming from the front, which in many cases require extensive repairs. Under the present conditions of the labour market, repairs are both slow and costly. The repairing work is not confined to the large establishments forming the Field Motor Car Company, but are also to be undertaken by smaller firms outside the combine. The Field Motor Car Company prefer to sell thoroughly repaired and reliable cars rather than to dispose of them unrepaired; their comprehensive and well organised repair department is rational and time and money saving, and yields more satisfactory repairs than those undertaken elsewhere at the instance of an individual buyer. In some cases the Field Motor Car Company, however, have been compelled to resort to so-called emergency sales of a limited number of unrepaired cars, from want of accommodation.

The fall in prices which was at one time apprehended has not set in; in fact, prices have rather stiffened, at any rate as regards motor lorries, which, it should be remembered, are not affected by the present high prices for leather and upholstery. Thus a 3-ton car in times of peace cost some 16,500 marks, with rubber tyres, whilst a war-time production of the same capacity, having wood and iron tyres, now costs at least 30,000 marks. The Field Motor Car Company sell a second-hand but thoroughly repaired car for 12,000 marks to 14,000 marks. The fact that the concern had at one time some 10,000 motor lorries on order also tends to keep prices up. Under these circumstances it is not to be wondered at that it has become impossible for private concerns to acquire motor lorries at reasonable prices.

In this connection it is expedient to refer to a decision arrived at some months ago by the Union of German Motor Car Manufacturers, to the effect that all orders received from private buyers prior to December 31, 1916, should be cancelled on the plea of the rise in the price of war materials and wages, and on account of the long duration of the war. Whether this decision can be legally supported is perhaps an open question, but in any case the manufacturers adhere to it; they certainly again accept orders, but only for delivery several years ahead, and they also make special reserves concerning the price. Many complaints are made concerning this state of affairs, it being claimed that at the present time everything ought to be done to ease the shortage of railway rolling-stock and the block on the lines by an extensive use of motor cars of all kinds. Before the war, there were probably between 7,000 and 8,000 motor lorries in use in Germany, an altogether inadequate number considering the size of the country. At the beginning of the war most of them passed under the control of the military authorities.

THE WORLD'S SHIPBUILDING.

Now that hostilities have ceased, "Lloyd's Register of Shipping" are able to publish statistics of shipbuilding in all countries except those of the enemy, and these reveal interesting developments in the United States, Japan and Sweden. In the first-named the output of oversea merchant shipping is double that of the United Kingdom; but it must be borne in mind that we have done an unprecedented volume of warship work. Moreover, the vessels in the United States are launched at a very early stage in their construction, and were figures prepared as to the tonnage placed in commission, the preponderance of the American figure would not be so great. Lloyd's figures do not include ships of less than 100 tons gross and take cognisance of vessels launched "whether they were completed during the year or are still under construction." Vessels having internal-combustion engines and sailing vessels fitted with auxiliary power are included with steamers.

United Kingdom Production.—Excluding vessels built to the order of the Admiralty for other than mercantile purposes, 301 vessels of 1,348,120 tons (viz., 300 steamers of 1,344,275 tons and 1 oil hulk of 3,845 tons) have been launched in the United Kingdom during 1918. These figures are 584,033 tons below the record figures of 1913, and represent an output 26 per cent. lower than the average of the three pre-war years 1911–13; they are, however, higher than the totals for the previous three years, the present total being 185,224 tons more than

THE WORLD'S SHIPBUILDING.

TABLE II.—TABLE SHOWING THE NUMBER AND TONNAGE OF MERCHANT VESSELS OF 100 TONS GROSS AND UPWARDS LAUNCHED IN THE VARIOUS COUNTRIES OF THE WORLD DURING THE YEARS 1892-1918.

Year.	United Kingdom.		Dominions.				Austria-Hungary.		Denmark.		France.		Germany.		Holland.		Italy.		Japan.		Norway.		Sweden.		United States.				Other Countries.		Totals.		Year.
			—		Canadian Lake Ports.																				Coast.		Great Lakes.						
	No.	Tons.	No.	Tons.	No.	Tons.	No.	Tons.	No.	Tons.	No.	Tons.	No.	Tons.	No.	Tons.	No.	Tons.	No.	Tons.	No.	Tons.	No.	Tons.	No.	Tons.	No.	Tons.	No.	Tons.	No.	Tons.	
1892	681	1,109,950	58	19,792	No	Returns	7	2,302	22	12,707	19	17,228	73	64,888	15	14,368	21	13,888	—	—	42	24,572	12	4,650	73	92,588	No	Returns	28	11,103	1,051	1,358,045	1892
1893	536	836,383	41	17,089	No	Returns	6	7,435	18	10,719	22	20,337	65	60,167	8	1,339	21	10,626	3	1,132	30	16,552	18	6,566	36	27,174	No	Returns	42	11,222	846	1,026,741	1893
1894	614	1,046,508	26	6,055	1	748	5	1,703	16	7,300	28	19,636	77	119,702	41	15,360	10	5,396	14	3,173	25	17,169	14	7,310	36	44,847	7	22,047	18	6,584	932	1,323,538	1894
1895	579	950,997	23	6,105	7	4,276	10	71	14	10,982	27	28,851	75	87,786	25	8,292	10	5,603	3	2,296	21	12,873	13	2,767	41	42,431	20	42,446	12	5,114	880	1,218,160	1895
1896	696	1,159,751	36	8,394	5	2,730	9	6,246	14	11,814	41	44,565	63	103,295	28	12,405	10	6,779	26	7,849	17	12,059	14	4,405	112	77,964	32	106,211	10	3,415	1,113	1,567,882	1896
1897	591	952,486	36	10,489	4	1,942	6	6,601	13	13,539	39	49,341	84	139,728	42	20,351	8	12,910	22	6,740	25	17,248	14	6,984	63	34,076	21	52,762	22	6,727	990	1,331,924	1897
1898	761	1,367,510	65	22,664	5	2,357	9	5,432	17	12,703	48	67,160	104	153,147	27	19,468	19	26,530	9	11,424	29	22,670	12	4,385	141	110,186	21	63,064	23	4,583	1,290	1,893,343	1898
1899	726	1,416,791	31	6,475	3	1,989	8	9,248	30	26,613	51	89,794	93	211,684	50	34,384	31	49,472	3	6,775	34	27,853	29	10,367	127	146,108	21	78,170	32	6,015	1,269	2,121,738	1899
1900	692	1,442,471	38	6,967	2	2,596	12	14,889	17	11,060	66	116,858	93	204,731	61	45,074	36	67,522	3	4,543	42	32,751	19	5,735	196	190,962	39	142,565	48	15,439	1,364	2,304,163	1900
1901	639	1,524,739	68	16,610	6	11,524	7	20,013	41	22,856	92	177,543	101	217,593	33	29,927	35	60,526	94	37,208	40	36,875	31	8,241	234	268,091	52	165,144	65	20,649	1,538	2,617,539	1901
1902	694	1,427,558	65	18,235	4	10,584	16	15,192	44	27,148	99	192,196	108	213,961	114	69,101	62	46,270	53	27,181	46	37,878	32	9,030	206	223,360	45	155,814	62	29,247	1,650	2,502,755	1902
1903	697	1,190,618	64	20,866	9	13,824	6	11,328	39	28,609	75	92,768	120	184,494	109	59,174	81	50,089	62	34,514	54	41,590	30	11,855	195	211,219	51	170,601	58	24,073	1,650	2,145,631	1903
1904	712	1,205,162	55	27,253	6	3,712	40	16,645	30	15,859	69	81,245	149	202,197	109	55,636	35	30,016	67	32,969	67	50,469	32	10,267	208	189,430	19	49,088	45	17,987	1,643	1,987,935	1904
1905	795	1,623,168	45	—	10,798		27	16,402	19	17,557	43	73,124	148	255,423	58	44,135	46	61,629	81	31,725	58	52,580	20	5,282	157	107,368	43	195,459	36	20,272	1,576	2,514,922	1905
1906	886	1,828,343	50	16,026	7	10,016	25	18,590	18	24,712	48	35,214	205	318,230	89	66 809	30	30,560	107	42,489	69	60,774	23	11,579	192	169,358	50	271,729	37	15,334	1,836	2,919,763	1906
1907	841	1,607,899	83	21,479	14	24,964	7	8,717	29	28,819	50	61,635	188	275,003	60	68,623	31	44,666	78	66,254	82	57,556	28	11,781	208	217,530	47	257,145	42	26,026	1,788	2,778,088	1907
1908	523	929,669	111	25,512	8	8,669	24	23,502	24	19,172	50	83,429	120	207,777	76	58,604	34	26,864	73	59,725	81	52,839	23	9,546	202	158,645	30	145,898	20	23,435	1,405	1,833,286	1908
1909	526	991,066	35	6,592	3	869	15	25,006	11	7,508	51	42,197	84	128,696	52	59,106	28	31,217	75	52,319	45	28,601	12	6,316	73	80,485	29	129,119	24	12,960	1,063	1,602,057	1909
1910	500	1,143,169	53	14,601	7	11,742	8	14,304	18	12,154	55	80,751	117	159,303	105	70,945	21	23,019	70	30,215	64	36,931	17	8,904	156	177,601	39	153,717	47	20,497	1,277	1,957,853	1910
1911	772	1,803,844	59	16,006	3	3,656	16	37,836	18	18,689	79	125,472	154	255,532	113	93,050	14	17,401	109	44,359	71	35,435	11	9,427	112	95,693	30	75,876	38	17,864	1,599	2,650,140	1911
1912	712	1,738,514	76	25,090	8	9,700	12	38,821	22	26,103	80	110,734	165	375,317	112	99,439	27	25,196	168	57,755	89	50,255	22	13,968	144	194,273	30	89,950	52	46,654	1,719	2,901,769	1912
1913	688	1,932,153	77	26,744	14	21,595	17	61,757	31	40,932	89	176,095	162	465,226	95	104,296	38	50,356	152	64,664	74	50,637	25	18,524	182	228,232	23	48,216	83	43,455	1,750	3,332,882	1913
1914	656	1,683,553	58	22,288	22	25,246	11	34,335*	25	32,815	33	114,052	89	387,192*	130	118,153	47	42,981	32	85,861	61	54,204	26	15,163	84	162,937	10	37,825	35	36,148*	1,319	2,852,753*	1914
1915	327	650,919	27	13,289	4	8,725	No	Returns	23	45,198	6	25,402	No.	Returns	120	113,075	30	22,132	26	49,408	59	62,070	27	20,319	76	157,167	8	20,293	10	13,641*	743	1,201,638*	1915
1916	306	608,235	36	22,577	4	8,994	No	Returns	28	35,277	9	42,752	No	Returns	201	180,197	10	56,654	55	145,624	52	42,458	34	26,769	167	384,899	44	119,348	18	14,296*	964	1,088,080*	1916
1917	280	1,162,896	80	66,475	25	27,996	No	Returns	23	20,445	6	18,828	No	Returns	146	148,779	11	38,906	104	350,141	44	46,103	4	26,760	266	821,115	60	176,804	27	32,538*	1,112	2,937,786*	1917
1918	301	1,348,120	184	230,514	22	49,390	No	Returns	13	26,150	3	13,715	No	Returns	7	74,026	15	60,791	198	489,924	51	47,723	6	39,583	741	2,602,153	188	430,877	40	34,478*	1,866	5,447,44 *	1918

* Returns not complete.

that for 1917 and 739,885 tons more than that for 1916. The whole of the output will be for registration in the United Kingdom, with the exception of 4 steamers of 12,325 tons built for French owners. The returns for 1918 show that 127 vessels of between 5,000 tons and 6,000 tons each and 45 vessels of 6,000 tons and upwards were launched; the largest was the Narkunda, of 14,500 tons. The average tonnage of steamers launched in the United Kingdom during 1918 is 4,481 tons; but, if steamers of less than 500 tons be excluded, the average reaches 4,593 tons, compared to 4,933 tons in 1917, 4,080 tons in 1916, 3,791 tons in 1915, and 4,460 tons in 1914. The launches for the year include 9 steamers with a total tonnage of 59,729 tons, which will be fitted with geared steam turbines. The "Standard" vessels launched during the year under review, amounted to 198, with a total tonnage of about 886,000 tons gross. Of steamers on the Isherwood system of longitudinal framing, 19 were launched during 1918 with a total gross tonnage of 123,773 tons, of which 15 of 98,162 tons are for the carriage of oil in bulk. The returns also include 29 other oil carriers of 156,414 tons, besides a number of other vessels designed for special services.

The output of leading ports is shown in Table I. The Clyde district occupies the first place among the shipbuilding centres of the country with an output of 348,760 tons (Glasgow 188,736 tons and Greenock 160,024 tons). Then follow the Tyne (266,594 tons), the Wear (260,553 tons), the Tees (209,711 tons), and Belfast (148,259 tons).

From Table II it can be ascertained that the tonnage launched in the United Kingdom during the five years 1894–1898 amounted to 74·7 per cent. of the total output of the world for that period. During the three following quinquennial periods it was 60 per cent., 59·8 per cent., and 61·1 per cent. respectively, thus showing that for the fifteen years 1899–1913 the United Kingdom's share of the world's output was quite 60 per cent. During the war years 1914–18 a very serious decrease has taken place, only 38·6 per cent. of the world's mercantile output for this period having been launched in the United Kingdom.

Other Countries.—Outside the United Kingdom, but exclusive of Germany and Austria-Hungary, there have been launched during the year, 1,565 merchant vessels of 4,099,324 tons (1,397 steamers of 3,996,924 tons and 168 sailing vessels of 102,400 tons). The figures show an increase of 131 per cent., as compared with those for 1917, and are 2,698,595 tons higher than those for 1913, the pre-war record year. An interesting feature in this year's totals is the amount of wood tonnage included. No less than 11,45,582 tons of wood vessels have been launched, which is nearly 28 per cent. of the total tonnage launched abroad during 1918. The countries where the largest output has taken place during the year under review are the United States, Japan and Canada. The totals for these countries amount to 3,781,145 tons, and account for 92 per cent. of the total output abroad.

TABLE I.—*Showing the Number and Tonnage of Merchant Vessels Launched in the Principal Shipbuilding Districts in the United Kingdom during the Three Years 1916–1918.*

District.	Total.		Total 1917.		Total 1916.	
	No.	Tons (Gross.)	No.	Tons.	No.	Tons.
Aberdeen	—	—	16	5,266	32	7,091
Barrow, Maryport and Workington	3	11,004	1	587	2	1,248
Belfast and Londonderry ..	23	148,259	19	148,057	4	16,386
Dundee	8	23,860	7	6,911	5	12,008
Clyde—						
Glasgow	41	188,736	41	185,551	26	79,208
Greenock ..	31	160,024	24	134,308	22	92,949
Hartlepools ..	25	100,413	13	65,622	11	54,295
Hull	5	25,480	18	20,037	68	26,846
Leith	11	20,421*	9	14,309	16	10,854
Liverpool	4	12,486	5	26,528	5	1,140
Middlesbro', Stockton and Whitby	24	109,298	23	109,306	27	31,342
Newcastle	55	266,594	52	231,907	35	133,336
Sunderland .	58	260,553	48	204,398	35	134,472

* Includes a sailing ship of 3,845 tons.

United States.—The output for the year 1918—viz., 3,033,030 tons gross—is a convincing proof of the great development in the shipbuilding industry which is generally known to have taken place in this country. This total for one year is higher than the whole output of the United States during the ten years 1907–1916; it is more than three times the amount launched during 1917, and it exceeds by over 25 per cent. the combined output of the rest of the world for the year 1918. The most striking increase has taken place in the yards on the Pacific Coast. The average yearly output on that coast during the four years 1912–15 was under 30,000 tons, in 1916 it was 123,882 tons, in 1917 it amounted to 428,622 tons, and during 1918 it has reached 1,514,296 tons. Of the total launched on the Great Lakes (430,877 tons) only 1 steamer of 5,429 tons is for trade on those lakes, all the other vessels being intended for seagoing purposes.

The total figures for the United States include 11 steel steamers of between 8,000 tons and 9,000 tons each, and 204 of between 5,000 tons and 8,000 tons; 326 wood steamers of over 2,000 tons, the largest being 8 of about 3,500 tons gross, each launched at Gulf ports; 188 vessels to be fitted with geared turbines, the largest being 3 of 8,775 tons each; 3 vessels of 1,370 tons each, fitted with turbo-electric system of propulsion; 93 steamers built on the Isherwood system of longitudinal framing, 22 of which, together with 5 other vessels, are for the carrying of oil in bulk, and 67 sailing vessels fitted with auxiliary power. Thirty-one per cent. of the total output is composed of wood vessels.

Japan.—The output for this country—489,924 tons—is the highest on record. It is 140,000 tons more than in 1917 and practically ten times the amount launched in this country during 1915. The totals include 36 steamers of over 5,000 tons each.

Canada.—The total tonnage launched during 1918 reaches 258,191 tons, 49,390 tons of which were launched on the Great Lakes. The figures include 42 wooden steamers, practically all of about 2,325 tons each.

Italy.—The total for Italy is 60,791 tons, about 22,000 tons more than the previous year, and is the highest total reached since 1905; it includes the largest vessel launched abroad during 1918, viz., the turbine steamer Esperia of 11,393 tons gross.

Holland, Sweden and France.—The tonnage of seagoing vessels launched in Holland amounts to 74,026 tons, which is only half the output for 1917. The figures for Sweden are the highest up to date; they show an increase of 50 per cent. on the 1917 totals. In France the diminution of output which has been going on since 1913 continued during 1918, when less than 14,000 tons were launched.

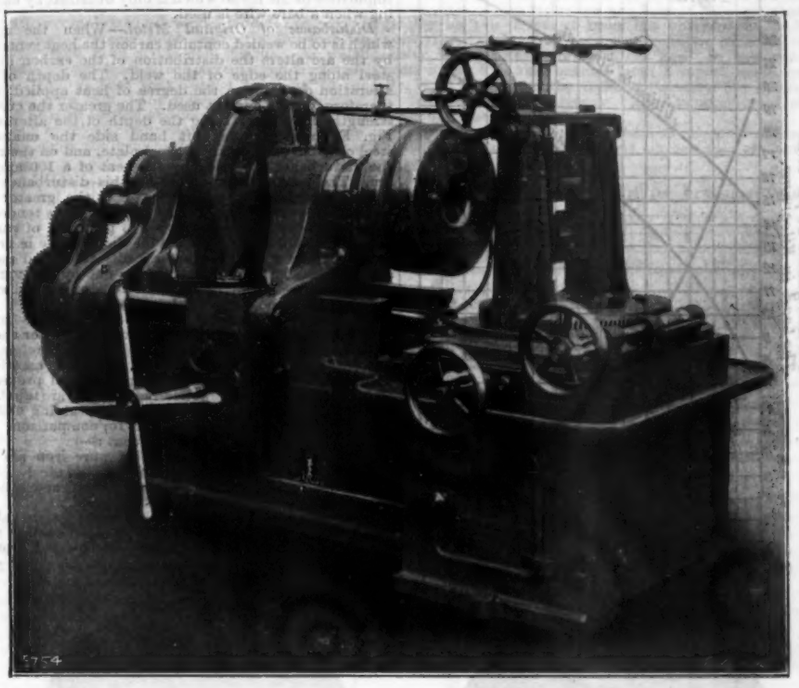
General.—The total mercantile output of allied and neutral countries for the year under review has been 5,447,444 tons. This figure has never been approached before in the society's annual summaries; it is over 63 per cent higher than the output of 1913, the record year prior to the war, which, of course, included the output of Germany, Austria-Hungary, &c. The number of steel ocean-going steamers of between 5,000 tons and 10,000 tons launched during 1918 amounted to 439, which represents 28 per cent. of the total number of such vessels in existence at the beginning of the war.

Of the merchant vessels launched during 1918, 900 of 3,501,344 tons (248 vessels of 1,085,159 tons in the United Kingdom and 652 of 2,416,185 tons abroad) are intended for classification in "Lloyd's Register Book." These figures include over four-fifths of the United Kingdom's output, and if the tonnage of all the steel steamers launched in the world is taken into account, nearly 75 per cent. of such tonnage has been built under the society's inspection. The total figures are the highest ever reached in the history of the society; they exceed by 1,431,000 tons the previous record total attained in 1913.

DISPOSAL OF WAR STORES, FRANCE.—A decree of February 6, published in the *Journal Officiel* of February 7, annuls the Special Office set up for the disposal and sale of war stores, noted in the *Journal* of January 23, and in its stead appoints an Under-Secretary of State under the Ministry of Finance to take charge of the disposal and sale of war stores with the necessary powers.

SCREWING MACHINE FOR BENT TUBES.

CONSTRUCTED BY MESSRS. JOSHUA HEAP AND CO., LIMITED, ASHTON-UNDER-LYNE.



THE screwing machine illustrated on the present page has been specially designed by Messrs. Joshua Heap and Co., Ltd., of Ashton-under-Lyne, for screwing the threads on long bent tubes largely used by shipbuilders and in the equipment of power stations. The machine is made in four sizes covering a range from 4 in. to 10 in.

The novel feature is the vice for gripping the tubes. This is designed to travel across the machine; it has a swivelling or rotary motion, and the grips, which are closed and opened by a right and left-handed square-threaded screw, can be above or below the centre line of the screwing dies. By utilising any or all of these movements it will readily be seen that bent tubes can be effectively held, and in the case of awkward bends the tube may be actually gripped on the bend or elbow.

The machine is fitted with a lead screw in order that accurate threads may be cut on the tubes.

The 4-in. and 6-in. machines are fitted with the makers' patent releasing motion by which the dies are instantly opened upon the completion of the thread, thus allowing the tube to be withdrawn from the dies without stopping or reversing the machine. In the two larger sizes of machine this special device is not supplied as it is necessary to stop the machine.

The machines are of substantial construction; all the gears are machine-cut, and a pump is fitted for the automatic supply of oil for the cutting dies.

ELECTRIC WELDING.*

By J. H. PATERSON, D.Sc.

IT is not possible in a single paper to deal effectively with every branch of electric welding, as this subject includes carbon arc welding, iron arc welding, and resistance welding with all its modifications, such as spot welding, seam welding, and butt welding.

Interest is centred mainly on the iron arc process, as this is the most adaptable of all the methods of electric welding, and in this paper it is the iron arc process alone which will be discussed.

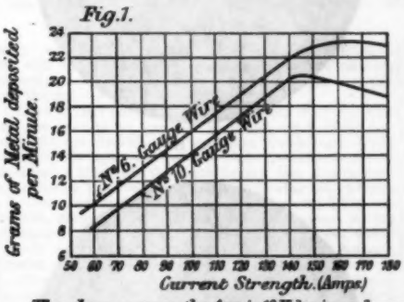
No attempt is made to describe the machinery or apparatus necessary in the application of this process, as it is within the capacity of any good electrical engineer to specify simple and satisfactory plant if the proper requirements are placed before him.

The Iron Arc.—When an electric current at sufficient pressure is passed between two iron rods which are in contact with one another, and which are then drawn slightly apart, an arc is started between the rods very similar in appearance to that produced between two carbons in the ordinary arc lamp. When such vertical iron rods are mounted so that they can be moved apart by a rack and pinion arrangement a magnified image of the arc can be thrown on the screen by a projection lens. The current passing is about 7 amperes, and the voltage drop across the arc is about 18 volts. The following phenomena are then readily noticeable:—

(*a*) A small globule of molten material is being produced at the end of the positive pole or anode.

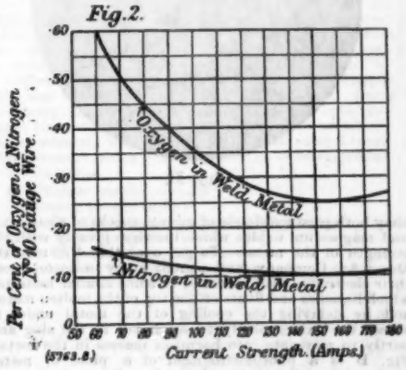
(*b*) A distinct hollow or crater is being formed at the end of the negative pole or cathode.

Fig. 1.



The drop across the Arc is 18 Volts in each case.
(5763.A.)

Fig. 2.



(*c*) The anode is much the hotter of the two poles, as shown by the distance along which it has become red hot. If the ball of material be detached from the anode and analysed, it will be found to consist mainly of iron and oxygen in combination, and if the amount of iron in it be carefully determined, the results show that some of this iron has been produced from the anode itself, and that some of it has come across the arc from the cathode, thus accounting for the hollow which was visible on that pole.

By careful experiment the author has found that, within certain limits of current strength, the amount of iron which is carried across the arc from the cathode to the anode and deposited there as oxide is proportional to the current passing, and is actually at the rate of about 0·0013 grammes per ampere per minute. The upper limit of current strength at which this phenomenon has been measured is about 15 amperes. The reason for this is that with higher strengths the iron poles get so hot that they begin to melt and drops of metal fall from the ends, thus preventing the collection and weighing of the deposits. It can be fairly assumed, however, that at all current strengths 0·0013 grammes of iron per ampere per minute are carried across the arc from cathode to anode, and deposited there as oxide. It follows, therefore, that all molten iron produced by using two iron surfaces as electrodes must contain oxygen if the arc be maintained between them in air.

The actual practice of welding consists in using an arc, of which one pole is the work, and the other pole a wire or electrode of varying thickness. The heat generated in the arc produces fusion of the surface of the metal composing the work, and at the same time melts the wire electrode which falls across the arc on an already molten surface, and thus effects a perfect union when the metal cools. As previously stated, a certain amount of metal is carried across the arc from cathode to anode, probably in the form of vapour, but in actual welding the amount of metal deposited in the weld is greatly in excess of the amount carried normally by the current.

In Fig. I the amount of iron deposited by a given current from a wire cathode is graphically represented by the upper curve. It will be seen that the amount increases considerably with the current strength, and as it consists of melted electrode is proportional rather to the heat developed in the arc than in the current strength. It is a debatable point as to how this molten metal crosses the arc from the electrode to the work. Some of it is undoubtedly carried across as vapour, but the greater portion is probably in the form of a rain of minute particles carried across by gravity. With a long arc quite large-sized drops of metal are formed, and traces of these drops surrounded by a thin layer of oxidised metal can be found in all welds. The projection of particles across the arc by the dynamic force of the current, so popular as an explanation of electric welding phenomena, is quite out of the question.

A glance at Fig. 1 will show that there is a maximum point for different thicknesses of electrode, beyond which the amount of metal deposited, instead of increasing steadily with the current, starts to fall away. This is due to excessive vaporisation and splashing of the metal, and marks the highest current strength which should be used for a given size of electrode. Up to this maximum point there is a nearly constant loss of about 5 per cent. of the electrode due to the vaporisation and burning of the depositing metal, so that these curves do not represent the actual weight of electrode used.

Polarity of Work.—One is frequently confronted with the statement that as metal is projected across the arc from the anode to the cathode it is the correct thing to make the work the cathode and the electrode the anode. As, however, the reverse is more probably true, it raises the question as to whether it is not the more correct method to make the work the anode and the electrode the cathode.

So far as the flow of metal is concerned, it does not matter which way the current passes, and under given circumstances equally good welds can be made by either method. As already pointed out, the anode is the hotter of the two poles, and it seems, therefore, more reasonable to make the work the anode when thick or moderately thick plates are to be welded. The conductivity of iron is so good that when the work has a considerable mass it is not an easy matter to obtain even surface fusion of the original metal with the arc; and unless the molten iron is very hot indeed, it cools in an incredibly short space of time, thus making for three dangerous conditions, viz., bad fusion at the junction with the original metal, a highly-stressed weld metal, and a rough, uneven surface, very difficult to clean and to detect faults in. It is safe, therefore, to say that except for very thin work ($\frac{1}{16}$ in. and below) the work should usually be the anode and the electrode the cathode. An important exception to this rule is dealt with later in the section on the mechanical properties of weld metal.

Chemical Composition of the Weld Metal.—If the bead of material obtained in the experiment described at the beginning of this paper be analysed, it will be found to contain a certain amount of nitrogen in addition to the oxygen. Thus a particular bead which was analysed was found to have the following composition:—

	Per cent.
Iron	71·05
Oxygen	28·74
Nitrogen	0·21

For this reason the metal deposited in the weld always contains oxygen and always contains nitrogen. The proporton of oxygen and nitrogen, as already explained, becomes less the greater the current strength employed to make the weld. The following analyses show the amount of oxygen and nitrogen contained in a metal

* Paper read before the Association of Engineering and Shipbuilding Draughtsmen at Newcastle-on-Tyne on Friday, February 14, 1919, Mr. O. J. Williams (Chairman, Technical Committee) in the chair.

deposited from a No. 10 gauge wire containing 0·15 per cent. of carbon at different current strengths :—

Current strength. Amperes.	Oxygen. Per Cent.	Nitrogen. Per Cent.
65	0·592	0·157
105	0·294	0·119
140	0·250	0·115

It will be seen that even at high current strengths the percentage of both these elements in the weld metal is much higher than is generally considered desirable in a commercial iron or steel.

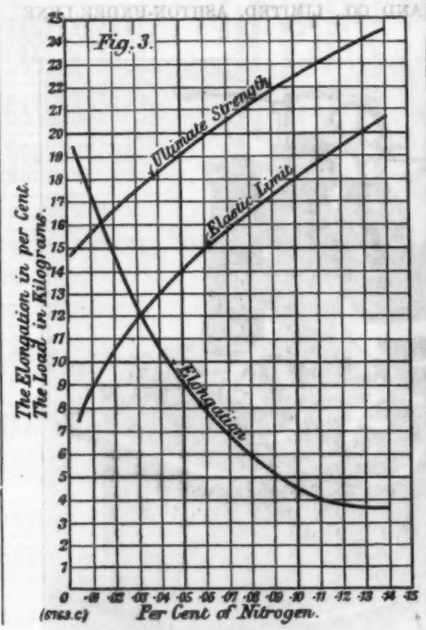
Fig. 2 shows graphically the percentage of oxygen and nitrogen which are contained in weld metal made with a No. 10 gauge electrode (bare) at different current strengths. The oxygen decreases rapidly from 0·60 per cent. at 60 amperes (which is about the lowest current at which metal can be deposited) to 0·25 per cent. at 140 amperes, after which it increases slightly. Reference to Fig. 1 will show that the point of minimum oxygen content corresponds to the point of maximum rate of deposition of metal.

Oxygen exists as oxide of iron in two forms in weld metal. One of these forms is oxide which has been dissolved in the molten metal and has been thrown out at the moment of cooling. This form is detrimental to the strength and toughness of the weld metal. The other form consists of globules or patches of unabsorbed iron oxide, and while in large quantities it may interfere with the strength of the metal, in small quantities it has no effect on its mechanical properties. The quantities of oxygen shown in the diagram consist of the total oxygen in the weld, so that the curve, while it is a measure of the dangerous dissolved oxygen, somewhat exaggerates its amount.

The analysis given at the commencement of this section shows the total oxygen.

The nitrogen contained in weld metal does not show anything like the same variation with current strength as oxygen does.

Some doubt exists in the minds of metallurgists as to the exact effect of nitrogen on commercial steels, but as in these cases the amount is rarely over 0·02 per cent., there is very little analogy between them and



weld metal. In a paper by Professor N. Tschischewski a diagram (Fig. 3) is given showing the effect of an increasing quantity of nitrogen on the ultimate strength, elastic limit and elongation of a steel wire of the composition : carbon, 0·14 per cent.; silicon, 0·18 per cent.; manganese, 0·45 per cent.; sulphur, 0·04 per cent.; and phosphorus, 0·03 per cent.

The embrittling effect of nitrogen is greatly increased when the metal containing it is chilled or rapidly cooled; and as this is a condition normal to weld metal, it will be recognised that the absence of this element would be a great improvement.

Oxygen produces similarly bad effects on the weld metal, but very successful attempts have been made to produce weld metal free from this element. There are a large number of elements which combine rapidly with the oxygen contained in molten metal and form harmless compounds. Such substances are known as deoxidisers, and the most commonly used ones are carbon, aluminium and magnesium. Carbon reacts with oxygen or iron oxide to form carbon monoxide, which, being a gas, mostly escapes from the fluid metal if time be given to it to accomplish this. The time taken for the metal to solidify in an ordinary run of weld on a ship plate is about one second and a half, and, therefore, a deoxidiser must be extraordinarily rapid to produce any effect. A steel wire containing about 0·7 per cent. of carbon when used as an electrode gives a weld metal with the following average composition :—

	Per Cent.
Carbon	0·152
Oxygen	0·161
Nitrogen	0·095

It is obvious, therefore, that carbon is not fast enough as a deoxidiser, as in an electric weld it can exist alongside considerable quantities of oxygen. In addition to this, any carbon not burnt out in the arc will in some parts of the weld exist in such a form as to produce even worse brittleness of the metal than the oxygen it displaces. The photomicrograph Fig. A, is from a piece of the weld metal having the above analysis, and shows the very brittle carbon structure referred to.

Aluminium and magnesium are commonly used as deoxidisers, and have an additional advantage in lowering the melting point of the weld metal slightly. When used with a bare electrode and too low a current strength they both produce clouds of minute specks of aluminium and magnesium oxides which interfere greatly with the strength of the metal. To get over this difficulty the Quasi Arc Company (and a great many imitators) coat their electrodes with asbestos, or some similar material, which liquefies and floats on the top of the molten metal, and by delaying the cooling of the metal under it allows the oxides partly to settle out in the slag and partly to segregate into harmless masses in the metal. Fig. B is a photomicrograph of a piece of metal made with a Quasi Arc electrode. Its analysis is as follows : carbon-trace, nitrogen = 0·098 per cent., oxygen 0·018. It appears to consist only of pure iron and small globules of slag. The nitrogen contained in the metal, and probably present as iron nitride, does not show itself under the microscope. Fig. C is a photomicrograph of a piece of metal containing no carbon, oxygen 0·33 per cent., and nitrogen 0·12 per cent., and shows oxides of iron separated out along the cleavage planes of the iron crystals.

Fig. D shows the same metal after annealing for 30 minutes at 850 deg. C., and shows a certain similarity to the structure in Fig. B, proving that a slag coating produces also an effect on the distribution of impurities in the metal which is only obtained by annealing when a bare wire is used.

Disturbance of Original Metal.—When the metal which is to be welded contains carbon the heat generated by the arc alters the distribution of the carbon in the steel along the edge of the weld. The depth of the alteration depends on the degree of heat applied, and, therefore, on the current used. The greater the current strength the greater being the depth of the alteration. Fig. E shows on the left hand side the unaltered steel of a 0·2 per cent. mild steel plate, and on the right the disturbance produced by the heat of a 100 ampere arc. The structure produced by this disturbance has a tendency towards brittleness, and the greater the carbon content of the plate the greater is this tendency. In mild steel containing below 0·3 per cent. of carbon it is the author's opinion that the disturbance is not of such a character as to produce a badly weakened metal, and this conclusion is amply borne out by the various mechanical tests which have been done on welded steel, and which will be discussed later.

Mechanical Properties of Weld Metal.—The metal deposited in a weld under ideal conditions is, or should be, identical with pure iron, and might, therefore, be expected to have the mechanical properties associated with that metal. The principal mechanical properties of dead mild cast steel (practically pure iron) are tabulated below, and those of mild steel plate containing 0·2 per cent. of carbon are placed alongside for comparison.

From these figures it is evident that :—

(*a*) The mechanical properties of pure iron are less affected by rapid cooling than those of mild steel.

(*b*) Pure iron has a lower elastic limit, and hence a lower factor of safety than mild steel plate.

(*c*) The capacity of pure iron to resist fatigue (alternating stress test) is less affected by rapid cooling than steel. As weld metal must be subject to rapid cooling, it follows that the nearer this metal can be got to pure iron in composition, the better will be the mechanical properties of the weld. This is more especially true as the effect of oxygen and nitrogen on the mechanical properties of iron is very similar to that of carbon.

Fig. A.

Fig. B.

Fig. C.

Fig. D.

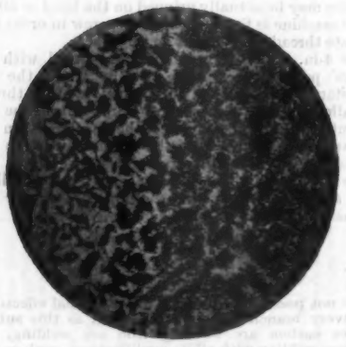
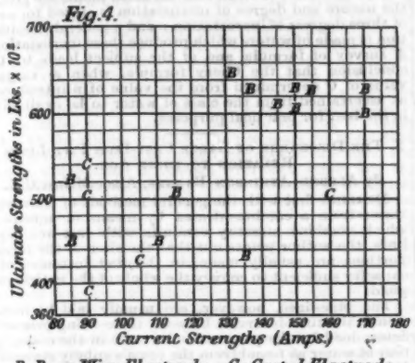


Fig. E.

Tons per Square Inch.	Dead Mild Steel. As Cast.	Dead Mild Steel. Quickly Cooled.	Rolled Steel Plate. As Rolled.	Rolled Steel Plate. Quickly Cooled.
Ultimate strength ..	22·7	22·0	32·84	39·9
Per cent elongation ..	31·0	30·0	25·0	15·75
Bend test	180 deg	180 deg.	180 deg.	75 deg.
Alternating stress test ..	270,000	269,000	300,000	210,000

The fact that pure iron has a lower elastic limit and ultimate strength than rolled mild steel leads to the conclusion that the ideal weld cannot have the original strength of the plate. As it is not unreasonable to suppose that (when such a weld can be obtained) it will not be more than 10 per cent. to 15 per cent. weaker than structural steel, such a weld will compare very favourably with any riveted joint used in practice, and structures containing such welds could be regarded as equal or superior to any joint used in practice in its capacity to stand both stress and fatigue. As welds made by existing processes all contain nitrogen or oxygen, or both, it follows that they cannot come up to the standard of pure iron. The following tables, selected from a number of results obtained within the last few months from a variety of sources on welds made on ships' steel plate, show the limitations of the process as at present carried out, and also the variations obtained by different operators and methods :—

Fig.4.



B-Bare Wire Electrode. C=Coated Electrode.

Fig.5.

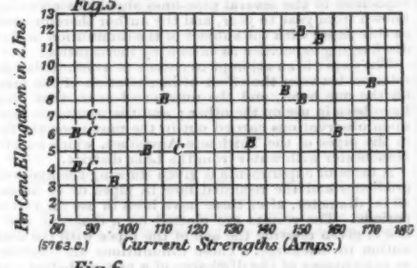
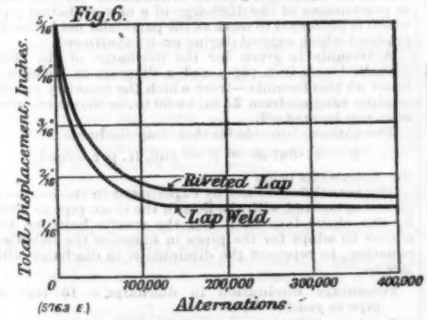


Fig.6.



No.	Per Cent. Comp. of Weld Metal. Carbon.	Total Oxygen.	Nitrogen.	Ultimate Stress, lbs. per sq. in.	Yield Point.	Elongation.	Bend Test, Degrees.	Electrode.
1	Trace	—	—	62,600	39,000	11·5	44	Bare wire.
2	—	—	—	61,100	35,650	8·5	55	Bare wire.
3	—	Trace	0·008	54,000	37,500	6·0	65	Coated.
4	Trace	—	0·091	50,000	37,100	6·0	78	Coated.
5	—	0·33	0·16	45,400	41,800	6·0	15	Bare.
6	—	0·07	0·087	53,500	38,000	12·5	95	Alloy wire.
7	—	0·28	0·112	62,700	42,400	9·0	34	Bare wire.
8	—	—	—	42,200	30,700	5·0	42	Coated wire.

All the above welds were made on half-inch ships' steel plate, which may be taken as having the average mechanical properties shown in the table (page 286) for mild steel plate.

The effect of the strength of current used in making a weld and its effect on the quality of the weld has already been referred to, and the two diagrams Figs. 4 and 5 illustrate by actual results the general improvement obtained with increasing current strength, so far as elongation and ultimate strength are concerned. It will be seen that high current strengths produce a greater number of strong and tough welds than low current strengths. One of the reasons for this is, as has been previously shown, that welds made at high current strengths (140–160 amperes) contain less oxygen and nitrogen than those made at the current strengths (80–100 amperes) generally recommended in this country. Another and more important reason is that the greater heat developed keeps the weld fluid for a longer period, allows a better structure to develop, and lessens the dangers of slag inclusions and flaws. It is true that greater skill is required from the operator at high current strengths, but once attained the dangers of faulty workmanship are infinitely less. In this connection the following extract from a report made by Mr. H. M. Hobart to the Welding Research Committee of the American Emergency Fleet Corporation is of especial interest :—

"The Wirt-Jones Tests, to which so many references have been made during the last six months, are now actually approaching completion. A comprehensive report will doubtless be made by Mr. W. J. Jones in collaboration with the Bureau of Standards people before the date of my next report to you.

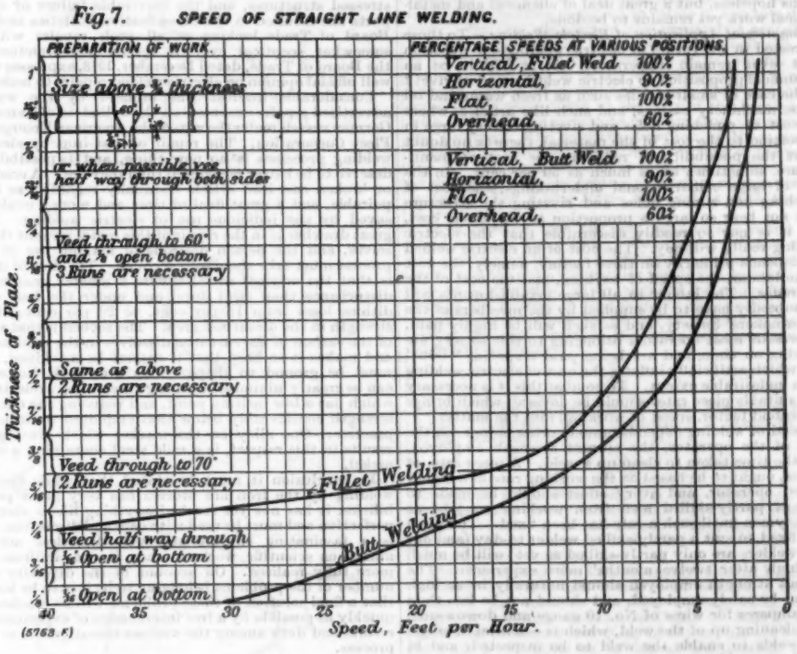
"I have myself devoted quite a number of hours analysing the results at present at hand, and while my conclusions are based on very hasty work, and while I consequently must reserve the right greatly to revise them when I have all the data before me, I may say that, so far as the results of this particular set of tests which were undertaken by Messrs. Jones and Wirt are indicative, they reveal no noteworthy difference in the mechanical characteristics of welds, whether these welds are made with bare metal electrodes or flux-covered electrodes, or whether the welding is done from D.C. or A.C. circuits. Plotting the results, however, in terms of the current employed, the dependency of the mechanical characteristics on the strength of current employed is very great indeed."

"As you will remember, the Wirt-Jones samples were welded in a dozen or more different places, and the operators or authorities at each place were given perfect freedom to choose the methods which seemed to them best. Although the weld was always on half-inch plate, and always of identical design, namely, double 'V' the currents employed in the different places ranged all the way from 80 amperes up to 175 amperes. For a preliminary analysis, I divided the results into two groups, the first group representing those in which the greatest currents were employed, and the second representing those in which the least currents were employed. The results for—

"1. Ultimate tensile strength ;
"2. Tension torque ratio ;
"3. Angle of bending at which cracking begins ;
"4. Per cent. elongation in 2 in.,

are shown in the following table :—

Fig.7. SPEED OF STRAIGHT LINE WELDING.


PREPARATION OF WORK.
PERCENTAGE SPEEDS AT VARIOUS POSITIONS.
Vertical, Fillet Weld 100%
Horizontal, 90%
Flat, 100%
Overhead, 60%
Vertical, Butt Weld 100%
Horizontal, 90%
Flat, 100%
Overhead, 60%
Size above ¾" thickness
or when possible vee half way through both sides
Veed through to 60° and ⅛" open bottom 3 Runs are necessary
Same as above 2 Runs are necessary
Veed through to 70° 2 Runs are necessary
Veed half way through ⅛" Open at bottom
⅛" Open at bottom
Fillet Welding
Butt Welding
Thickness of Plate.
Speed, Feet per Hour.
(5763 F)

—	Ultimate Tensile Strength in Lbs. per Sq. In.	Tension Torsion Ratio.	Angle of Bending at which Crack Starts.	Per Cent. Elongation in 2 In.
A. Averages of ten welds with heavy currents	57,100	0.83	47.2	8.1
B. Averages of nine welds with light currents	44,200	0.66	34.0	5.2
Ratio of A.-B.	1.29	1.26	1.39	1.56

"I believe that you will agree that the significance of the large value of the ratio of A to B is very considerable, and it would take skilled welders to weld with the rapidity necessary to avoid too high a temperature when heavy currents are used ; but it would seem to be important to have the most skilled welders attempt to make welds on half-inch plates of exactly the same angle with 200 amperes or more, and contrast these welds with others made with equal care with 100 amperes and less.

"If the indications of the present results are borne out in such tests, the first-mentioned condition will yield welds ranging around 60,000 lb. per square inch, while under the last-mentioned condition the tensile strength will be of the order of 35,000 lb. to 45,000 lb. per square inch. Under the first-mentioned conditions the bending angle will be of the order of 50 deg., and under the second-mentioned conditions the bending angle will be in the order of 30 deg. Under the first-mentioned condition the per cent. elongation in 2 in. will be of the order of 8 per cent. to 10 per cent., and under the second conditions the per cent. elongation in 2 in. will rarely be over 4 per cent. to 5 per cent."

While it is evident that every argument appears in favour of the use of high current strengths, in so far as the quality of the weld metal is concerned, there are other considerations which make great care in the use of these heavy currents essential. The temperature, and hence the degree of expansion, of the metal to be welded becomes greater as the current across the arc rises. If a weld by reason of its design prevents the movement of the edges of the plates which are being welded, strains may be set up in the weld metal greater than it can stand, and the weld will crack. Such strains can only be reduced by decreasing the temperature of the weld, and this is accomplished by reducing the current strength. Mr. J. T. Carr, of Messrs. Swan and Hunter, has drawn the author's attention to a case of this sort. A long strapped butt weld was being made on a somewhat large structure. The weld metal was continually giving way, and it was only cured by changing the polarity of the work from positive to negative, and thus reducing the temperature of the weld. It is conceivable that in some welds it will be necessary to sacrifice elasticity and toughness by doing the work at a low current strength, in order to produce a weld as free as possible from internal stresses.

The modulus of elasticity of weld metal is of great importance, but unfortunately this quantity has not obtained the attention it deserves. Professor Abell has communicated the results of Lloyds' tests, which show that the modulus is the same as that for steel and iron in general ; but these results were obtained from metal deposited by the Quasi Arc process, and this process is by no means typical of all others.

It is obvious that if the modulus of a weld metal be higher than that of steel, stresses applied to the welded structure will be transferred from the weld metal to the contiguous steel at points where, owing to the disturbance of the steel, it is least able to bear these stresses. On the other hand, a lower modulus will transfer stresses to the weld metal which, owing to its limited volume, would be unable to stand them.

A great many structures are subjected to continuous alternations of stress below the elastic limit of the metal, and it is, therefore, of great importance to know how welds stand up to the fatigue induced by these stresses as compared with rolled steel plate. The author has seen samples of welds made with bare wire electrodes

withstand as many alternations as the original plate, although on the whole the want of uniformity in this direction is very marked. The following diagram (Fig. 6) taken from Lloyds' report shows the capacity of a Quasi Arc lap weld to withstand alternating stresses of various magnitudes as compared with a riveted lap joint. There is, however, a great deal of work to do in this direction before definite opinions can be given on this very important subject.

To put the whole matter very briefly, electric welds may be considered, when properly made, to be quite comparable with a riveted joint in all structures in which the stresses are evenly distributed, when these stresses are continuous or alternating. In structures liable to severe accumulated stresses this method of joining up steel is not to be relied upon entirely, because our present control over the composition of the weld is not to be relied upon. The problem is by no means hopeless, but a great deal of chemical and metallurgical work yet remains to be done.

Commercial Application of Electric Welding.—To those interested in the future of electric welding one question must ever remain uppermost, viz.: Will it be an economical proposition to electric weld instead of rivet? In the case of small articles such as fresh water and oil tanks, machinery casings, and such like articles, where the cost of punching holes and riveting is very large in proportion to the cost of the material, there is no doubt about the possibility of reducing the cost of manufacture, sometimes by as much as 50 per cent. In the case of large constructional undertakings, the cost of punching and riming holes and riveting the structure does not bear so large a proportion to the whole cost, and it is not so readily discernible that the electric welding really will pay. The cost of an electric welded job depends primarily on three factors, namely, the cost of the labour, the speed of working, and the cost of the electrodes. The labour in all large establishments will undoubtedly have to be supplied by the members of the Boilermakers' Society, and as such will be highly paid. At present most operators belonging to this society are working on time, and are being paid a special "lieu" rate which artificially inflates the cost of electric welding to an undesirable extent. To combat this it is necessary that suitable piece rates should be devised, which brings the second factor, speed of working, into the matter.

Speed of welding depends, among other things, on the skill of the operator, the current strength employed, and the time taken to clean up a weld. A piece rate, of course, ought to be based on the working rate of a higher skilled operator, and every effort should be made to prevent partly-skilled men from working on jobs as journeymen until such a rate has been fixed. The piece rate fixed to suit a partly-skilled welder to-day (and our best welders are only partly-skilled as yet) will be much too high after twelve months' more experience. The current strength employed should naturally be as high as can be safely employed, and should not be less than 100 amperes for wires of No. 10 gauge and downwards. The cleaning up of the weld, which is essential in single run welds to enable the weld to be inspected, and in multi-run welds, to prevent slag and oxide inclusions, will vary very much with the amount of deposit on the surface of the weld metal. Slag-covered welds take a lot of cleaning, and, therefore, slow down the speed of working very considerably. Welds with bare electrodes require some cleaning up, and electrodes coated with the coatings of volatile material to steady the arc require least cleaning of all. The cleaning of a weld of the latter type if properly done takes 30 per cent. of the time occupied in making the weld.

The rates of welding shown on the curve (Fig. 7) are taken from a paper by Mr. H. Jasper Cox, read before the American Society of Naval Architects, November 14, 1918. While the relative speeds are correct enough, the actual speeds are wholly fallacious. In the text Mr. Cox suggests that 50 per cent. of these speeds is nearer the mark, but in the author's opinion 25 per cent. of the speeds would be still nearer when cleaning of the weld is included.

Finally, the cost of the electrode itself must be considered. Without going into detail, it may be stated that electrodes which cost more than 60*s.* per cwt. of metal in them cannot be used with much hope of economy instead of riveting. This places all the slag-covered electrodes known to the author out of the question at once. This may seem a sweeping statement, but it must be borne in mind that in addition to the high initial cost of these electrodes they are slower in working, and the finished weld requires a great deal of cleaning up. Without doubt some of the welds made with these electrodes show excellent properties, above the average for the bare wire electrode, but that does not alter the fact that the future is with the cheap electrode which makes a weld practically free from surface slag; and the most which can be done at the price in the way of coating will be to wash the outside of the wire with some volatile material which will preserve the electrode and increase the conductivity of the arc. Deoxidisers and denitrogenisers must be contained in the electrode metal, and the time necessary to produce a good structure in the weld be obtained by increasing whenever possible the temperature of the weld metal or reducing its solidifying point. A prolific source of bad workmanship is the highly oxidised weld produced by using too long an arc, thus causing the electrode to melt off in a series of drops instead of a rain of minute particles. Workmen engaged on piece work are particularly prone to this evil in their endeavour to speed up the job they are working on. This can be remedied entirely by reducing the open current voltage to such an extent that a long arc cannot be made. It is found quite possible in practice to work steadily, and make excellent welds with an open current pressure of 45 volts, and a generator designed to distribute its maximum current at 60 volts is highly suitable for welders working on piece rates.

Electric Welding as a Method of Repair.—All the above remarks on the cost of welding apply, of course, to new works, and not at all to repair jobs. It is often possible by the proper application of weld metal to repair apparatus which would otherwise require replacement. In such cases cost does not matter so much, as the difference between the value of the article and the cost of the repair is generally very great. Worn shafts and other moving parts made of steel can be built up to their original dimensions with a comparatively trivial outlay, and in boilers, worn landing edges, and leaky seams may effectively be brought to something like their original condition. Owing, however, to the very varied skill of the operators at present available, and the lack of experienced advisers, operations have often been carried out on dangerously worn material and highly stressed structures, and the inevitable failure of these parts has resulted in the Classification Societies and the Board of Trade looking on all such repairs with a somewhat sceptical eye. A recent memorandum of the Board of Trade, dated December, 1918, expresses very well official opinion on electric welded repairs to boilers.

Considerable interest was aroused by the widely advertised repairs executed on the cylinders of damaged German vessels under the ægis of the American Emergency Fleet Corporation. The repair of cast-iron by electric welding processes is no new thing, and its possibilities deserve to be better recognised than they are. A cracked or broken cast-iron article is usually regarded as irrepairable, and a great deal of time and money could be saved by the judicious use of electric welding. Two great drawbacks in the repair of this metal present themselves, and the person desirous of making use of the process must take them into account. The first of these is that the original metal suffers a greater amount of disturbance than steel does, and under the best conditions loses from 15 per cent. to 20 per cent. of its strength in the disturbed area. The second is that some of the carbon in the cast-iron dissolves in the weld metal and makes it so hard that it cannot be machined, but must be ground to shape. This drawback, however, can be greatly minimised by using a steel alloy as electrode which has a low melting point, and reducing the current strength considerably below that employed in ordinary practice. One alloy on the market which gives good results in this respect, is a mild steel containing a little nickel.

In conclusion it must be stated that while electric welding by the iron arc process has very great possibilities, it has not yet reached anything like a state of perfection and must be used with care and discretion. It is a fascinating subject and will doubtless attract numerous scientific workers when its possibilities are more fully realised. On account of the diversity and number of the problems belonging to it, it is to be hoped that a final solution of these problems will be reached as quickly as possible by a free interchange of experimental results and data among the various investigators of the process.

THE FLOW OF WATER IN LARGE PIPES AND TUNNELS.*

1. The Flow of Water in Pipes and Pressure Tunnels.

By Frederick John Mallett, Assoc.M.Inst.C.E.

The paper is an endeavour to trace out the inconsistencies met with in many of the older formulæ, and briefly to set out the features that in practice determine the ultimate capacity of water-mains.

Practically all the better-known formulæ have been examined and compared, and the formulæ giving the most consistent results over a range of diameters from 3 in. to 120 in. have been tabulated. It was found that many of the formulæ gave good results over a short range of diameters, but when extended to the diameters that are now coming into use they gave unreliable results. This is no reflection upon those who originated the formulæ, as prior to 1910 only about a dozen pipes over 48 in. in diameter had been tested.

The well-known Kutter-Flynn tables with a value of 0·013 for n have been extensively used by waterworks engineers, but while giving good results for mains, say, from 12 in. to 36 in. in diameter, for mains of small diameter the capacity was found to be greater than the formula predicted, although the incrustation was the same in amount and character. This knowledge has compelled the adoption of a smaller value of n for pipes below 12 in. or so in diameter; or indeed sometimes of another formula. The necessity for two formulæ or two values of n to determine with a degree of accuracy the discharge of mains similarly encrusted is objectionable.

It was with the idea of obtaining greater accuracy in determining the flow of water in incrusted mains that tests were made upon mains 3 in. to 30 in. in diameter, and upon their entire length, not in short sections or straight runs. These mains have been in use from twenty to sixty years, and the water is derived from the limestone and red sandstone formations which produces an incrustation corresponding to Kutter's $n = 0{\cdot}013$. About the time these tests were completed (1916), Mr. F. C. Scobey's work on wood-stave pipes (Bulletin No. 376, United States Department of Agriculture) was issued. The experiments were made upon mains 8 in. to 162 in. in diameter, and form reliable data upon which to construct formulæ for mains up to about 15 ft. in diameter. Since the date of Scobey's bulletin, the tests upon the New York water-supply tunnels of 14½ ft. diameter have been issued, and these have been considered in the development of a new set of formulæ for clean and incrusted mains.

It has been noted that in the past the greatest attention has been paid to the determination of coefficients and indices in formulæ for clean mains, and then a very wide margin allowed for incrustation or ageing. Generally the allowance for incrustation is the same relative amount for the large mains as the small mains, which is not tenable. Several expressions have been introduced to determine the reduction in capacity of mains in a term of years, but these are also inconsistent with fact, since the incrustation depends more upon the class of water conveyed by the main than upon the number of years that the main has been in use.

New formulæ for clean and incrusted mains are given; the nature and degree of incrustation is stated for each of three degrees of incrustation; and a general classification is made of waters which produce these incrustations. A survey of formulæ and of the subject leads to the conclusion that the Chezy formula, when a varying value of C determined from the value of n introduced, as ascertained from the class of water to be dealt with, is the best for practical purposes.

2. The Discharge of Large Cast-Iron Pipe-Lines in Relation to their Age.

By Alfred Atkinson Barnes, Assoc.M.Inst.C.E.

Dealing first with the general methods of conveying water from a catchment-area by means of aqueducts which combine masonry conduits with cast-iron pipe-lines, the author points out that the sizes of the former portions are usually made, in the first instance, of a capacity sufficient to convey the whole of the anticipated yield.

The pipe-lines, however, are usually laid by instalments, the time-intervals between these being primarily determined by the progressive increase in the consumption of water as found from the town's supply statistics. Hence it is important that the individual discharging capacities of the several pipe-lines should be accurately known from year to year, and the author therefore deals in this paper with the subject of the diminution in those discharging capacities as caused by incrustation.

The paper is an attempt to reduce to a definite law the relation between the effect of incrustation of the mains on the one hand, and the number of years that these have been in use on the other; and the results are based upon observations carried out in the past upon the flow in the pipes of the Thirlmere Aqueduct, which supplies Manchester with water from the Lake district.

A table of experiments is given showing the hydraulic gradients and the recorded flow in pipes of 44 in. and 40 in. diameter, after these have been in use for various periods. The results are plotted on a diagram, and a law is given relating the age of the pipes with the diminution in discharge. These diminutions are expressed as percentages of the discharge of a new asphalted pipe, which is presumed to work at the particular net hydraulic gradient which existed during each experiment.

A formula is given for the discharge of the clean asphalted cast-iron pipe, and a diagram is included—based on this formula—from which the quantity passing in pipes ranging from 24 in. to 60 in. in diameter, when new, can be read off.

The author's formula for this clean discharge is:—

$$Q = 47 \cdot 087\, d^{2 \cdot 760}\, s^{0 \cdot 529} \text{ cub. ft. per second,}$$

the dimensions being in feet.

The actual flow found by experiment in the incrusted pipe is compared with the flow in the clean pipe as given by the above formula; and the results have led the author to adopt for the pipes in question the following equation, to repesent the diminution in discharge with age:—

$$\text{Percentage diminution in discharge} = 13\ (\text{age of pipe in years})^{0 \cdot 37}.$$

In view of the seriousness of the rate of derease of flow in the early years, the policy is suggested of adopting some system of cleaning the pipes before the incrustation is very far advanced.

Engineers in charge of other aqueducts are invited to test the formula on large pipe-lines which have been conveying soft moorland water for some years, in order that the design of pipe-lines in the future may be based upon some agreed percentage reduction in discharge when compared with that of a clean pipe.

* Abstracts of two papers read at the meeting of the Institution of Civil Engineers, on Tuesday, February 25, 1919.

German Electric Generation and Distribution.—A large State, or at least State-controlled scheme for the generation and supply of electric energy in Germany is said to be in course of preparation by the German Ministry of Finance. The aim is to bring about the most economical and most rational exploitation of Germany's sources of current generation, both the production and the distribution to be regulated by law. There are in Germany over 4,000 electricity works, and this, of a necessity, must entail a very material waste, a situation of which German experts have been aware for years and to the improvement of which they have paid much attention. The less profitable concerns are to be abandoned, and those more favourably placed are to be helped and extended. The country is to be divided into a number of supply districts, exclusively according to technical and economical considerations. Within these districts the different works will be made to co-operate or to combine together so as to avoid undesirable competition. The scheme comprises the exploitation both of the coal deposits in Northern Germany and the water power in the more southerly districts.

SLIDING FRICTION IN BALL BEARINGS.

By MR. ARVID PALMGREN.

THE great value of ball bearings, both from an economical and from a purely technical point of view, may now be looked upon as generally acknowledged. With the growing attention which these modern machine elements attract, the interest in a more thorough study of their peculiar features naturally increases. The present investigation proposes to elucidate theoretically how the sliding friction occurs between balls and races of modern ball bearings of different types. It is manifest to every one with any experience of the practical application of ball bearings that the friction, more especially the sliding friction, must be the test of the efficiency of the bearing, particularly at high speeds. Many other factors, certainly, influence the efficiency, such as the quality of the material and the accuracy of the workmanship, the nature of the lubricant, the loads and various working conditions. When it is a question, however, of comparing the merits of different ball-bearing constructions, the sliding friction supplies a fair basis of comparison. So as to confine this investigation, as far as possible, to practical cases of some importance, the numerical examples only apply to the two important main types of radial bearings, the single row groove bearing and the double row spherical bearing.

In order to be able to calculate the loss of energy due to the sliding friction it is necessary to know both the deformation of the small surfaces of the balls and races which come in contact with each other, and the distribution of the stresses within the respective contact surfaces; this knowledge, unfortunately, is incomplete, inasmuch as it rests on the formulas theoretically deduced by Heinrich Hertz (1881), which have only partially been verified by experiment. Even the Hertz hypothesis, however, that the reactions are at right angles to the contact surfaces, that the bodies are elastic and isotropic, that they are in a state of rest as against each other, and that the limit of elasticity be not exceeded, show that the application of the formulas to the conditions within a ball bearing must be taken merely as an approximation. As in this case it more especially is a question of comparing different constructions, these considerations do not constitute any very serious drawback.

As, in the first instance, regards the form of the pressure surface, the pressure figure, according to Hertz, generally takes the form of an ellipse. The semi-axes of this ellipse, a and b, are functions of the curvature of the bodies in contact with each other, the elastic moduli and the load. Hertz gives the functions of these semi-axes as :—

$$a = \mu \cdot q, \; b = \nu \, q, \qquad . \quad . \quad (1)$$

where

$$q = \sqrt[3]{\frac{3\,P\,(\partial_1 + \partial_2)}{8\,(\rho_{11} + \rho_{12} + \rho_{21} + \rho_{22})}} \qquad . \quad . \quad (2)$$

and P denotes the load, whilst ∂_1 and ∂_2 are constants depending on the material of the bodies defined by the relation

$$\partial = \frac{4}{E} \cdot \frac{m^2 - 1}{m^2}$$

E being = the Young's modulus and m the reciprocal of Poisson's ratio; consequently when $m = \frac{10}{3}$, $\partial = \frac{3{\cdot}64}{E}$, ρ_{11} and ρ_{12} represent the inverse values of the principal radii of the one body, ρ_{21} and ρ_{22} correspondingly denote the principal curvatures of the other body, μ and ν are coefficients, depending on an auxiliary angle, τ, which is defined by the equation

$$\cos\tau = \frac{\sqrt{(\rho_{11}-\rho_{12})^2 + 2(\rho_{11}-\rho_{12})(\rho_{21}-\rho_{22})\cos\omega + (\rho_{21}-\rho_{22})^2}}{\rho_{11}+\rho_{12}+\rho_{21}+\rho_{22}}$$

ω here being the angle between the normal planes corresponding to indices 11 and 21.

The functional relationship between μ, ν and τ can be expressed by means of an auxiliary angle ϵ by the formulas

$$\sin^2\frac{\tau}{2} = cotg^2\epsilon \, \frac{F(\epsilon) - E(\epsilon)}{E(\epsilon)}$$

$$\nu = \mu \cos\epsilon = \sqrt[3]{\frac{2}{\pi}} E(\epsilon) \cdot \cos\epsilon,$$

$F(\epsilon)$ and $E(\epsilon)$ signifying the complete elliptical integrals of first and second order, having $\sin\epsilon$ for modulus. Thus

$$F(\epsilon) = \int_0^{\frac{\pi}{2}} \frac{d\phi}{\Delta\phi}$$

$$E(\epsilon) = \int_0^{\frac{\pi}{2}} \Delta\phi \cdot d\phi.$$

$$\Delta\phi = \sqrt{1 - \sin^2\epsilon \sin^2\phi}.$$

By taking a series of values of ϵ, one can from these formulas, by the aid of tables of elliptical integrals, calculate a number of corresponding values of τ, μ, ν, and subsequently from these we can by interpolation find the values of μ and ν, corresponding to a given value of τ. These values, to a decimal accuracy, can be derived from the scales in Fig. 1.

In the following investigation

r = the radius of the ball.

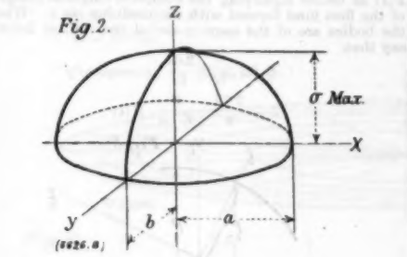
r_1 = the radius of curvature of the ball race in the direction of the movement of the ball.

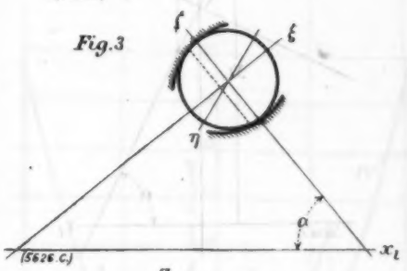
r_2 = the radius of curvature of the ball race in a direction at right angles to the direction of the movement of the ball.

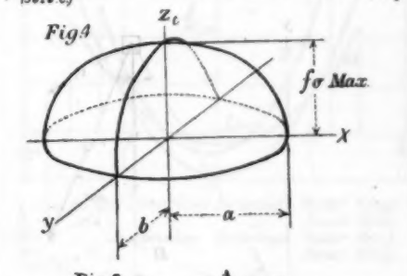
A radius, the centre of which falls within the body, is reckoned positive, and a radius, the centre of which is outside the body, negative; that means that a concave surface has a negative radius, and a convex surface a positive.

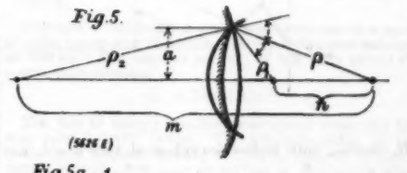
Substituting the functions defined above in

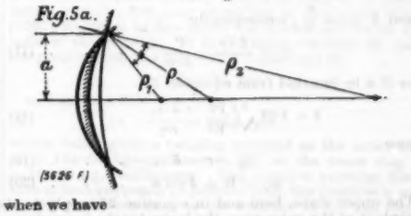
$$a = \mu \, q, \; b = \nu \, \rho, \qquad . \quad . \quad (3)$$











when we have

$$q = 1{\cdot}40 \sqrt[3]{\frac{P}{E}} \cdot \left[\frac{r\,r_1\,r_2}{r\,r_1 + r\,r_2 + 2r_1\,r_2}\right] \qquad (4)$$

The axes of the pressure ellipse lie in the normal sections corresponding to the radii r_1 and r_2.

In the case when $r_1 = r_2$, τ becomes = 90°, and thus $\mu = \nu = 1$, and

$$a = b = 1{\cdot}11 \sqrt[3]{\frac{P}{E} \cdot \frac{r\,r_1}{r + r_1}} \qquad . \quad (5)$$

The projection of the pressure area is thus known as regards form and size. The stresses on the different elementary layers of the pressure surface arising from deformation in the bodies, vary, according to Hertz, as the third co-ordinate of a half-ellipsoid having the pressure ellipse as a base. The co-ordinate system is chosen so that the x y plane is tangent to the surface at its centre, whilst the x axis coincides with the semi-axis a and the y axis with the semi-axis b, and the third axis, or z axis, is at right angles to both. Relatively to the ball-bearing as a whole, the x and z axes lie in the same plane as the axis of the bearing, the positive direction of z corresponding with the outward drawn radius.

The ellipsoid which represents the normal stress, Fig. 2 which may be called the normal stress ellipsoid, has, according to Hertz, the following equation :—

$$Z = \frac{3\,P}{2\,\pi\,ab}\sqrt{1 - \frac{x^2}{a^2} - \frac{y^2}{b^2}} \qquad . \quad (6)$$

From this it results directly that the maximum stress at the centre of the ellipse amounts to

$$\sigma_{max} = \frac{3\,P}{2\,\pi\,ab} \qquad . \quad . \quad (7)$$

If the values of a and b in equations 3 or 5 are inserted in equation 7, σ_{max} can also be obtained as a function of P, E, r, r_1 and r_2.

In considering the relative motion of the ball and the races the ball will be supposed fixed in space and the races of the bearing supposed to rotate in opposite directions. By this supposition the immaterial centrifugal stresses on the ball are neglected and the ball will, too, in the following, be considered as of no weight. The centre of the ball is taken as the origin of a right-angular system of co-ordinates $\xi\,\eta\,\zeta$, the ξ and ζ axes lying in the same plane as the axis of the bearing and with their positive directions outward from the centre of the bearing. The positive direction of the η axis is supposed to point outwards from the plane of the paper, Fig. 3. The ξ axis is taken so that it lies at right angles to the line joining the centres of pressure of both contact surfaces. The ζ axis forms the angle α with the axis of the bearing.

It is obvious that the ball may rotate round both the ξ axis and the ζ axis. The angular velocity round the ξ axis may be ω_2. Knowing this and the respective radii from the axes, the angular velocity of both ball races can be determined. If R_y signifies the radius from the axis of the bearing to that point or those points on the outer ball race which are at rest in relation to the ball, and ω_y the angle speed of the outer ball race, then with sufficient accuracy

$$\omega_y = \frac{r'}{R'_y}\,\omega_2 \qquad . \quad . \quad . \quad . \quad (8)$$

where r' is the radius from the points mentioned to the ξ axis. Similarly, if the subscript i is taken to refer to the inner race

$$\omega_i = \frac{r''}{R''_i}\,\omega_2 \qquad . \quad . \quad . \quad . \quad (9)$$

Equations 8 and 9 are exact in two cases, viz., when the angular velocity round the ζ axis is 0 or when the point $\xi = 0$ is in relative rest. They are in general approximately correct, both these conditions being approximately fulfilled.

For calculating the loss of energy arising by sliding between ball and ball races, it is necessary both to examine the relative velocities corresponding to the opposing pressure surfaces, and also to determine the frictional resistance which is, of course, always excited in such a direction as to oppose the motion taking place. Its maximum value is assumed to be a certain fraction of the normal pressure at each part, and therefore be also represented by an ellipsoid, as indicated in Fig. 4.

If the friction coefficient be f, then the value of the tangential force will therefore be determined by the equation :—

$$Z_t = f\,\frac{3\,P}{2\,\pi\,ab}\sqrt{1 - \frac{x^2}{a^2} - \frac{y^2}{b^2}} \qquad . \quad . \quad (10)$$

The relative speeds and their directions depend on the shape and position of the deformed contact surfaces.

Hertz has also determined the shape theoretically. As his determination is, however, much too complicated to be suitable for use in this investigation, it will be necessary to be contented with an approximation, resting upon the result, also arrived at by Hertz, viz., that the depressions at two contacting points are equal in both bodies as long as these are of the same material. On this assumption it is possible to obtain an expression for the form of the deformation surface in space. Thus, if ρ_1 and ρ_2 signify the constant curvature radii of both surfaces in a certain plane before the deformation and ρ the common, approximately constant curvature radius after the deformation, the three radii which are drawn from the common point of the three curves, will be so directed that the radius ρ bisects the outer or inner angle between the radii ρ_1 and ρ_2 (Fig. 5 and 5a).

In the zz-plane the semi-axis a (Fig. 5) of the pressure ellipse is so small in proportion to ρ_1 and ρ_2 that one may put

$$\rho = \rho_1 + n,$$

$$\rho = m - \rho_2$$

Further,

$$\frac{n}{\rho_1} = \frac{m}{\rho_2}.$$

These three equations give

$$\rho = \frac{2\,\rho_1\,\rho_2}{\rho_2 - \rho_1}$$

or inserting the values on the radii of curvature in the zz- plane

$$\rho = \frac{2\,r\,r_2}{r_2 - r}. \qquad (11)$$

According to Hertz, formula 11 is exact if both bodies are spheres.

So as to simplify the calculations to some extent the differences in speed, which might arise on account of the

varying radii in the yz plane and the planes parallel with the same are left out of consideration. The order of size of these speed variations is entirely different from, and smaller than, those considered in the calculation, so that this approximation is quite legitimate.

If, at a contact, the projections of the tangential forces in all directions were = 0, the position of the pressure ellipse in the co-ordinate system $\xi\,\eta\,\zeta$ would be such that the centres of both ellipses would fall on the ζ axis. Should this, however, not be the case, but a certain frictional force exist during the rolling, at right angles to the rolling direction, the centres of the said ellipses would be removed into the $\xi\,\zeta$ plane.

This, as regards the spherical bearing, would mean a reduced amount of sliding, as the ball would then roll more like a cone (Fig. 6) with the vertex nearer the axis than would otherwise be the case. A single row ball bearing with both races grooved, on the contrary, which generally rolls like a cylinder against a cylinder, would roll more like a cone with the axis at such angle to the axis of the bearing, that the friction would thereby be increased (Fig. 7). How such side friction really manifests itself during rolling has apparently not been duly examined so far and may probably form the subject of further investigations by and by.

Accepting the hypothesis that no side friction of this kind occurs, the resultants of the normal pressure will pass through the centre of the ball. This supposition

Fig. 6.

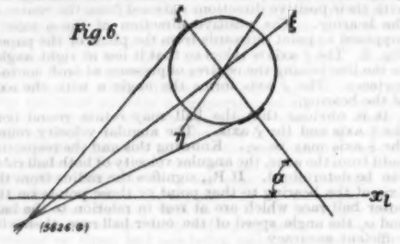
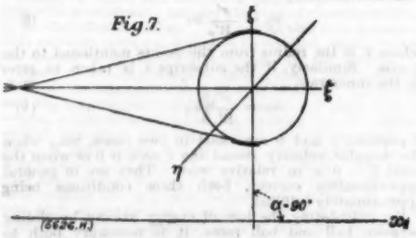


Fig. 7.



infers that the result may turn out less advantageous for the spheric bearing than the facts justify.

The position of the pressure surfaces in the $\xi\,\eta\,\zeta$ system having thus been determined, and their shape being known, it is possible to calculate the speed differences for different surface elements within the pressure surfaces.

It will then first be observed that the movements in a surface may be looked upon as composed of a linear motion and a rotatory movement. If the ball be prevented from rotating round the ζ axis, approximately straight-lineal movements would arise on account of the unequal radii to the points of the pressure surface, which movements are parallel with the y axis. The amount of this straight-lineal movement at different points is easily determined, when one knows the shape and position of the deformed surface. The deformed surface in the $\xi\,\zeta$-plane generally forms a circle with the ρ radius and with the central point on the ζ axis (Fig. 8).

The axis of the bearing is denoted by x_l, and the axis at right angles to this passing through the centre of the ball by y_l.

In order further to elucidate the matter, the formula for the speed difference at the outer ring is deduced, all the points on the ball move round the ξ axis with the angular velocity ω_2, and all points on the outer ring round the x_l axis with the angular velocity ω_y. Equation 8 holds good as regards the mutual relation between these two angular speeds. When $\xi = 0$ then $\zeta = \zeta_1$, and when $x_l = -\zeta_1 \cos\alpha$ then $y_l = y_{l_1}$.

The speed of the points of the ball now becomes

$$v_2 = \zeta\,\omega_2$$

and the speed of the points of the ring :—

$$v_a = y_l\,\omega_y.$$

The difference in speed is thus

$$v_r = y_l\,\omega_y - \zeta\,\omega_2 \quad . \quad . \quad (12)$$

Then

$$\zeta = \sqrt{\rho^2 - \xi^2} + \zeta_1 - \rho \quad . \quad . \quad . \quad (13)$$

Further,

$$y_l = \sqrt{\rho^2 - [x_l - (\rho - \zeta_1)\cos\alpha]^2} + y_{l_1} - \rho\sin\alpha \quad . \quad (14)$$

when

$$x_l = \xi\sin\alpha - \zeta\cos\alpha.$$

consequently, the difference in speed becomes

$$v_r = \omega_2\left[\frac{r'}{R'}\left(\pm\sqrt{\rho^2 - (x\sin\alpha \mp \cos\alpha\sqrt{\rho^2 - z^2})^2} + y_{l_1} \mp \rho\sin\alpha\right) - \sqrt{\rho^2 - z^2} + \rho - \zeta_1\right] \quad . \quad (15)$$

ξ being exchanged for x. (See Fig. 8.)

The lower signs for the inner ring are arrived at in an analogous manner, when the terms in the equation correspond to signs in Fig. 9. It should be noticed that ζ_1 and r' are always reckoned positive.

In equation 15, ζ_1, y_{l_1}, r' and R' are still unknown. As regards ζ_1 and y_{l_1}, these are very nearly equal to r and R respectively. If δ is the approach between the two bodies under load P, then according to Hertz

$$\delta = \frac{3\,P}{8\,\pi}(\partial_1 + \partial_2)\int_0^\infty \frac{dz}{\sqrt{(a^2 + b^2 z)(1 + z^2)}} \quad (16)$$

If here $z = tg\,\phi$ and

$$b = a\cos\epsilon$$

then

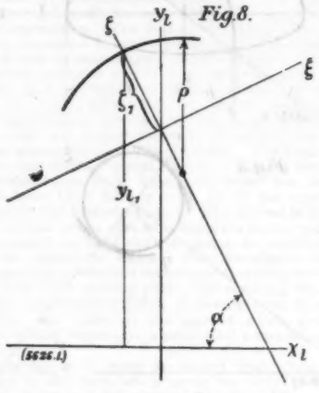
$$\delta = \frac{3\,P}{8\,\pi}\,\frac{\partial_1 + \partial_2}{a}\,.\,F(\epsilon),$$

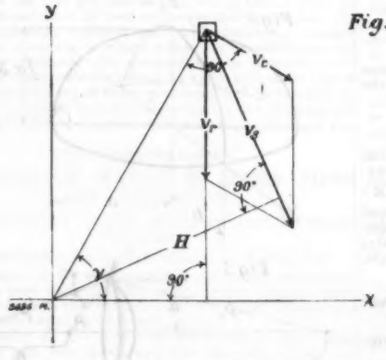
$F(\epsilon)$ as before signifying the complete elliptical integral of the first kind formed with the modulus *sin* ϵ. When the bodies are of the same material one can, as before, say that

$$\partial_1 = \partial_2 = \frac{3{,}64}{E}, \text{ consequently}$$

$$\delta = \frac{2{\cdot}73}{\pi}\,.\,\frac{P}{E\cdot a}\,.\,F(\epsilon)$$

Fig. 8.





If, besides, both bodies are spherical, then $a = b$, $\epsilon = 0$ and $F(\epsilon) = \frac{\pi}{2}$, consequently

$$\partial = \frac{2{\cdot}73}{2}\,.\,\frac{P}{E\cdot a} \quad . \quad . \quad . \quad (17)$$

or if a be inserted from equation 5

$$\delta = 1{\cdot}23\sqrt[3]{\frac{P^2}{E^2}\,.\,\frac{r + r_1}{rr_1}} \quad . \quad (18)$$

now

$$\zeta_1 = r - \delta \quad . \quad . \quad . \quad . \quad (19)$$

$$y_{l_1} = R \pm \delta\sin\alpha \quad . \quad . \quad . \quad (20)$$

The upper signs, here and in equation 22, apply to the contact at the outer ring, the lower for the inner ring.

R' and r' are the radii to the points which are at rest relatively to each other, that is, for which $v_r = o$. According to our hypothesis, the projections in all directions of the tangential forces in a pressure surface = 0. Under the straight-lineal movement in question, all the tangential forces will be parallel to the y axis. As all points in the surface, with exception of the lines, where the speed alters direction, i.e., the 0 lines are in a state of movement relatively to each other, the tangential force has in each point its maximum value, the size of which is determined by equation 10. The result as regards the equilibrium conditions for the position of the o lines will then be this, that those parts of the volume of the tangential stress ellipsoid, which correspond with the movement in one direction, should be equal to the parts of the same volumes which correspond with the movement in the opposite direction. The speed directions are obtained as positive or negative according to the value of v_r in equation 15. The v_r-curves become bent and intersect the x axis in one or two places. With $\alpha = 90°$, the v_r curve becomes symmetrical round the v axis. The o lines thus divide the ellipsoid in such a manner that the central part includes the same volume as the sum of the outer parts. Through integration of these volumes it will be found that the o lines for $\alpha = 90°$ will be at a distance $\pm 0{,}346a$ from the origin, Fig. 10.

For the annular ball bearing, which has $\alpha = 90°$

$$r' = \sqrt{\rho^2 - 0{,}121\,a^2} - \rho + \zeta_1 \quad . \quad (21)$$

$$R' = y_{l_1} \mp \zeta_1 \pm r' \quad . \quad . \quad (22)$$

Fig. 9.

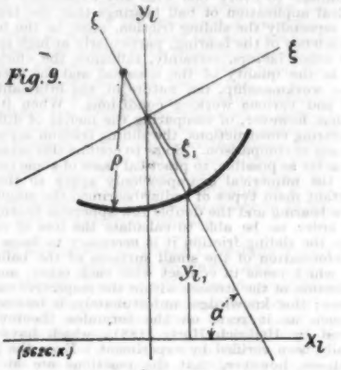


Fig. 10.

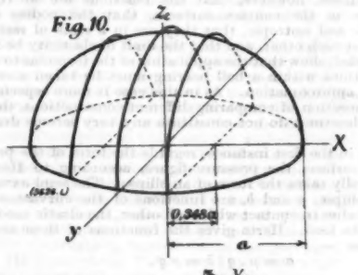
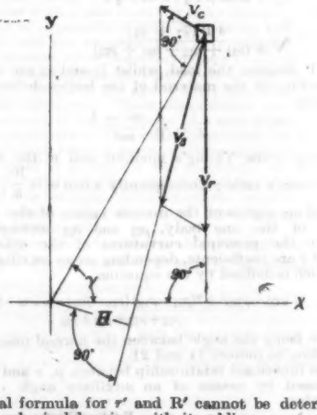


Fig. 11.



a general formula for r' and R' cannot be determined for the spherical bearing with its oblique contact, but must be calculated for each separate case.

If the expressions arrived at for ζ_1, y_{l_1}, r' and R' are inserted in equation 15, one obtains the speed difference v_r as a function of known quantities.

In addition to this straight-lineal movement, a rotary movement round the ζ axis, may, as already mentioned, occur. Should the moment at the outer and inner pressure surfaces be different in the case of the ball being prevented from rotating round the ζ axis, then a rotation would occur round this axis in the direction of the greater movement if the ball is allowed to rotate round the ζ axis. The angular speed of this rotation is determined (see Fig. 11) by the circumstance, that the rotation of the ball is not accelerated during motion. Hence the two moments at the contact surfaces must be equally great. If, thus, the rotating movement takes place with the angular speed ω_c each point in the pressure surfaces of the ball attains a speed proportionate to corresponding points in the ball races, and this speed is

$$v = \omega_c\sqrt{z^2 + y^2} \quad . \quad . \quad (23)$$

If the ball at the same time attains an angular speed round the axes ξ and ζ the relative speed between the points of the pressure surfaces will in quantity and direction be composed of v_r and v_c, according to the law of parallellograms, Fig. 11.

The resulting speeds are signified by v_s and for this is obtained the expression :—

$$v_s = \sqrt{(v_r \pm v_c\cos\gamma)^2 + v_c^2\sin^2\gamma}.$$

The upper signs apply to such points, where v_r and v_c

twist in the same direction round the origin, and the lower signs hold good, when the opposite occurs.

Now

$$\cos\gamma = \frac{x}{\sqrt{x^2+y^2}}$$

$$\sin\gamma = \frac{y}{\sqrt{x^2+y^2}}$$

and consequently

$$v_z = \sqrt{\left(v_r \pm v_c \frac{x}{\sqrt{x^2+y^2}}\right)^2 + v_c^2 \frac{y^2}{x^2+y^2}} \quad . \quad . \quad (24)$$

In order to calculate the effective moment it is also necessary to know the leverage of the force round the origin. If this be signified by H, then it will appear from Fig. 11 that

$$H = \frac{v_r x + v_c \sqrt{x^2+y^2}}{v_z} \quad . \quad . \quad . \quad (25)$$

v_c and v_r being inserted with different signs for different directions of twist.

In order to form an idea of how large the frictional loss may become in practice, the writer has calculated values for the loss of energy at the inner and outer ring both in a single row ball bearing with both races grooved and in a spherical bearing of standard dimensions. As the integrals in question are refractory, the calculation has been made by approximate formulas, the respective pressure surfaces each being divided into 100 equally large surface elements, having the forms and positions shown in Figs. 12 and 12a.

Bearings with 50 m.m. inner and 110 mm. outer diameter and 27 mm. breadth have been chosen as examples, Fig. 13.

For the spherical bearing

$r = 7{\cdot}1425$ mm.
$R_y = 47{\cdot}81$ mm.
$R_i = 33{\cdot}56$ mm.
$r_{2_y} = r_{1_y} = -47{\cdot}94$ mm.
$r_{1_i} = 33{\cdot}655$ m.m.
$r_{2_i} = -7{\cdot}70$ mm.
$a = 85°46.$

according to Stribeck's calculations, is :—

$$P = 192 \text{ kgs.},$$

when the bearing contains 13 balls. Owing to the symmetry

$$\omega_c = 0.$$

The friction coefficient for both bearings has been taken as

$$f = 0{\cdot}1.$$

In order to elucidate the effect of the sliding friction as completely as possible, the results of the numerical examples are embodied in Table I, which comprises both the total losses through sliding for the respective bearings as well as the maximum losses per square millimetre and the mean losses per square millimetre for the respective surfaces in both types of bearing. It should be noted, as already mentioned, that the figures cannot be accepted as absolute values, but must be considered more in the light of relative figures. An extremely important circumstance which must be taken into account in this connection is the uncertainty of the friction coefficient assumed.

Fig. 12.

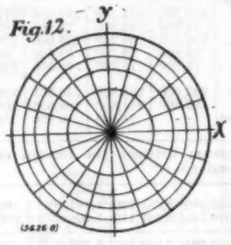


Fig. 12 A.

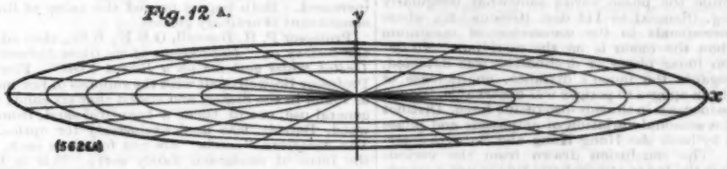


Fig. 13.

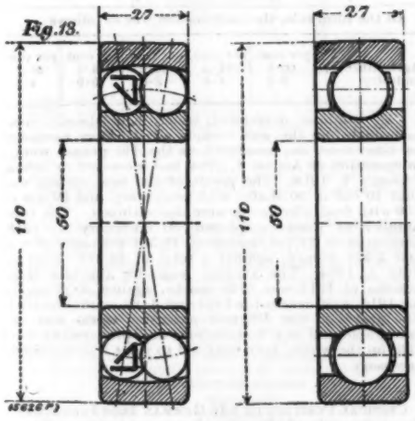
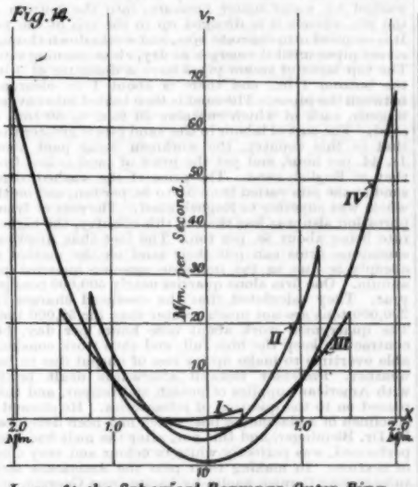


Fig. 14.



I - v_r At the Spherical Bearings Outer Ring.
II - " " " " " Inner Ring.
III - " " Annular Bearings Outer Ring.
IV - " " " " Inner Ring.

The reaction for a certain surface element $dx\,dy$ will be

$$Z_{r_{(xy)}} = Z_i\,dx\,dy \quad . \quad . \quad . \quad . \quad (26)$$

the twisting moment of this will then be

$$d\,M = H\,Z_i\,dx\,dy \quad . \quad . \quad . \quad (27)$$

and the moment for the whole surface

$$M = \iint H\,Z_i\,dx\,dy \quad . \quad . \quad . \quad (28)$$

the limits for this double integral are so fixed as to comprise the whole pressure ellipse.

When the ball during steady motion does not acquire any accelerated movement, the two twisting moments, as pointed out above, must be equally great. Consequently,

$$M_y = M_i \quad . \quad . \quad . \quad . \quad (29)$$

After having determined ω_c from this equation or given ω_c such a value, that it satisfies this equation, we may proceed to calculate the loss of energy at the respective surfaces. If the loss of energy be signified by N, the same, per surface element, will become :—

$$d\,N = v_r\,Z_i\,dx\,dy \quad . \quad . \quad . \quad (30)$$

and the entire loss

$$N = \iint v_r\,Z_i\,dx\,dy \quad . \quad . \quad . \quad (31)$$

The limits being fixed so as to comprise the whole surface.

In a ball bearing the pressure on a ball varies during its motion round the periphery, that is, the load P is variable with the angle, which the radius through the centre of the ball forms with the direction of the pressure from the axis of the bearing. Other quantities, however, also influence this function, such as the strength of the rings in proportion to the number of balls, the material, &c., for which reason this function is difficult to determine and varies according to the different methods of construction. The total effect of the sliding friction can, therefore, not be generally determined by the calculations made above, although they afford a basis for comparing different types of bearings.

The axis of the bearing was taken to revolve at a speed of 1,000 r.p.m. and the loads on the bearing was assumed at 500 kg. The angular velocity of the balls round the ξ axis then becomes

$$\omega_\xi = 289{\cdot}1 \text{ 1/sec.}$$

The loss of energy has been calculated when the ball was most heavily laden. The absolute value of this load, from reasons already set forth, cannot be determined exactly, but may according to Stribeck's views (1901) be taken as five times the mean load for all the balls of the bearing. If the bearing contains 26 balls the greatest load per ball would in this case be

$$P = 96 \text{ kgs.}$$

ω_c has been found to be

$$\omega_c = 0{\cdot}45 \text{ 1/sec,}$$

which value gives a twisting moment at the outer ring of + 165·04 kg—millimetre, and at the inner ring of —168,20 kg.—millimetre. The positive twisting direction is here supposed to proceed from the positive x axis to the positive y axis, as the rotation of the ball round the ξ axis takes place from the positive η-axis to the positive ζ axis.

The pressure surfaces have, by a graphic construction, been divided into elements, and the centre of gravity co-ordinates of these elements determined.

For the annular ball bearing

$r = 8{\cdot}7325$ mm.
$R_y = 49{\cdot}50$ mm.
$R_i = 32{\cdot}035$ mm.
$r_{1_y} = -49{\cdot}50$ mm.
$r_{2_y} = -9{\cdot}40$ mm.
$r_{1_i} = 32{\cdot}035$ mm.
$r_{2_i} = -9{\cdot}10$ mm.
$a = 90°$

At 1,000 revolutions

$$\omega_2 = 135 \text{ 1/sec.}$$

with 500 kilograms load the greatest load on the ball,

TABLE I.

Loss of Energy through Sliding.	Spherical Bearing. kg-mm./sec.	Annular Ball Bearing. kg-mm/sec.
Total loss	130·8	308·6
Total loss at an outer pressure surface	4·1	81·1
Total loss at an inner pressure surface	61·3	227·5
Maximum loss at an outer pressure surface per sq. mm.	32·0	160·0
Maximum loss at an inner pressure surface per sq. mm.	290·0	450·0
Mean loss at an outer pressure surface per sq. mm.	9·4	52·0
Mean loss at an inner pressure surface per sq. mm.	84·7	163·0

A closer investigation of the quantities concerned plainly shows that the spherical bearing is, on the assumptions above made, much superior. A good illustration of the mutual amount of sliding speeds of the two types of bearing is afforded by Fig. 14, which graphically represents the function v_r, which is the entirely preponderant factor. It is also perfectly clear that the sliding is bound to increase rapidly with increasing breadth of contact between ball and ball races.

No doubt it is theoretically possible to design an annular ball bearing so that the sliding friction is reduced to a minimum, but in practice the necessity of providing for some axial thrust has to be met.

MOTIONS OF SUN, EARTH, MOON; MODEL.—In two lectures, delivered before the Royal Institution on the two last Thursdays, Dr. William Wilson, M.B., F.R.A.S., of London, demonstrated the use of models which he has designed for explaining the motions of the Sun, Earth and Moon. His chief model consists of a brass rod, or axis, horizontally supported at the centre with the sunball mounted above the pivot and the earth and moon at the one end of the rod, the other end bearing a counterweight. When the rod is turned by hand about its centre the three bodies describe their several movements; on the table, on which the model is placed, is spread a sheet, about 5 ft. in diameter on which degrees and the months are marked. By a large number of spindles, pulleys and cords, the movement of the axial rod is communicated to the several bodies. The vertical system, supporting the earth and moon, consists of five concentric tubes, *e.g.* All these parts can easily betaken to pieces, and separate parts can be clamped to explain special features and to show, for instance, how the seasons would change if the inclination of the axis of the earth to the ecliptic were changed. The retrograde movement of the nodal line (the line joining the nodes), the points at which the moon's orbit cuts the ecliptic at an angle of about 5 deg.), and the forward movement of the line of apses (joining the perigee and apogee, the points at which the moon is nearest to the earth or furthest away from it) can also be demonstrated and it is remarkable that Dr. Wilson's model should indicate the Saros or Chaldean period of 18 years 11 days (6,585 days) and of 223 lunations (after which the 70 solar and lunar eclipses of a cycle re-occur in the same order, because the nodal line has completed one revolution) correct within one day after having travelled a good deal all over the country for a number of years. In this large model all the orbits are circular; smaller specimen models reproduce the eccentricity of the moon's orbit and explain the movement of the apses more fully. Dr. Wilson makes his main driving wheel expansible, provides his pulleys with rims of carborundum paper and inserts tension regulators into his cords. Properly explained the models should certainly prove very useful for the elucidation of the movements of our earth and of the sun and moon.

ROYAL METEOROLOGICAL SOCIETY.

THE usual monthly meeting of this society was held on Wednesday, the 19th inst., at the Society's Rooms, 70, Victoria-street, Westminster, Sir Napier Shaw, F.R.S., President, in the chair.

Dr. S. Chapman read a paper entitled "*The Lunar Tide in the Earth's Atmosphere.*" The lunar tidal variation of barometric pressure had been well determined at Batavia, from fifty years' hourly record, and from shorter series of data, extending over about five years in each case at St. Helena, Singapore, Rome and Samoa. As very little was known about its dependence on latitude, season and the distance, declination and phase of the moon, a new and detailed discussion has been made of thirty and twenty-eight years' record of barometric pressure at Batavia and Hong Kong respectively. The results are described in this paper, and considered alongside the pre-existing values from the stations above named, together with the Greenwich determination recently published in the Quarterly Journal of the Society. It appears that the amplitude varies approximately as the fourth power of the cosine of the latitude, while the phase varies somewhat irregularly from 33 deg. (Samoa) to 114 deg. (Greenwich), where 90 deg. corresponds to the occurrence of maximum pressure when the moon is on the meridian. No dependence on lunar phase or declination was detected, while as regards the moon's distance, an increase of amplitude from apogee to perigee was observable, though less than the increase in the tide-producing force. Distinct evidence of a seasonal variation of amplitude and phase was shown by both the Hong Kong and Batavia determinations. The conclusion drawn from the various results is that the lunar atmospheric tide is not a simple tidal phenomenon, but is complicated by other effects, notably by resonance with an adjacent free period of vibration of the atmosphere, and possibly also by more local causes, such as the rise and fall of the ocean.

Mr. Miller Christy also read a paper entitled "*The Gunfire on the Continent during* 1918: *its Audibility at Chignal St. James, near Chelmsford.*" Observations on the audibility of the Continental gunfire have been made by the author for four years. The results for previous years were brought forward in earlier papers. In 1918 the first sounds were heard on the evening of May 8 and the last on August 26, thus confirming previous experience that there is audibility at the writer's post of observation in Essex only during the summer months The period of audibility in 1918 amounted to 15 weeks 5 days. In previous years the periods were 1915—17 weeks, 3 days; 1916—15 weeks; 1917—19 weeks 4 days. The average for the four years is 17 weeks. A feature of 1918 was that the sounds were less loud and distinct than in previous years and there were none of the periods of extreme loudness which had before been noticed.

SWEDISH IRON WORKS AND MINES IN GERMAN POSSESSION.—The estate of the recently-deceased Lübeck Senator Possehl comprises considerable interests in Swedish iron works and mines, including the large Fagersta concern, with blast furnaces and very extensive possessions, also the Carlsdal concern, and shares in mining property in Dalecarlia and other iron works. The most important item, however, is some 50,000 shares in the large Grängesberg-Oreläsund concern which controls the bulk of the Swedish iron ore export; and for which Possehl was the representative for Central Europe. A large portion of the Grängesberg shares was formerly owned by an English financier who parted with them some years ago. The Possehl estate also controls a large part of the shares in the Orkla Mining Company, Norway.

UNITED STATES MINERAL OUTPUT IN 1917.—We read in *Commercial America*, Philadelphia, that the value of the minerals produced in the United States in 1917 was 5,010,948,000 dols., an increase of 1,496,976,000 dols., or about 43 per cent. over the former record of 3,513,972,000 dols. established in 1916. The blast-furnace products (pig-iron and ferro-alloys), copper, coal and petroleum contributed 74 per cent. of the total value of minerals produced and 88 per cent. of the increase in 1917. The metals established a new record in 1917, being valued at nearly 2,092,000,000 dols. and representing 42 per cent. of the total value of the mineral product. They showed an increase of 471,316,000 dols., or about 29 per cent. over the 1,620,508,000 dols. reported for 1916. The blast-furnace products contributed nearly 90 per cent. of the total increase. Increases were also made in the value of aluminium, copper, lead and silver, but decreases were recorded in the value of gold and zinc.

THE ELECTRICAL APPOINTMENTS BOARD.—The Electrical Appointments Board (see Institution Notes, No. 7, page 26, June, 1918) have on their register applications for employment from a considerable number of members of the institution at present serving in His Majesty's Forces and expecting early demobilisation, or recently demobilised. The board desire to impress upon all employers the strong claims of these members in regard to priority of employment, and they will be glad to receive particulars of vacancies in the electrical industry. On receipt of particulars the board will submit to the employer the names of applicants possessing qualifications similar to those desired. No fees are charged. Communications should be addressed to The Secretary, the Electrical Appointments Board, 1, Albemarle Street W.1. The first members of the board are: Mr. L. B. Atkinson, Mr. F. Crawter, Mr. F. Gill, Mr. J. S. Highfield, Mr. H. C. Levis, Mr. W. R. Rawlings, Mr. R. T. Smith, Mr. C. P. Sparks. Mr. J. Swinburne.

SOCIETY OF GLASS TECHNOLOGY.

THE February meeting of the above society was held at the University, Sheffield, on February 19, 1919. Mr. J. Connolly occupied the chair. The first paper, entitled "*The Properties of the Lime Soda Glasses*; (2) *The Resistance to Water and other Reagents*," by J. D. Cauwood, M.Sc., Constance Muirhead, B.Sc., and W. E. S. Turner, D.Sc., was read by the last named. Several glasses had been melted on a small scale, and the lime content had been increased by definite amounts. The resistance of each glass to the following reagents: water, caustic soda solution, sodium carbonate solution, hydrochloric acid, had been tested. In every case it was found that increasing the lime content brought about increasing resistance.

The second paper, "*The Properties of the Lime Soda Glasses*; (3) *The Thermal Expansions*," by S. English, M.Sc., and W. E. S. Turner, D.Sc., was read by Dr. Turner. The same series of glasses mentioned above (*i.e.*, lime contents increasing to 10 per cent) had been tested in regard to thermal expansion. It had been proved that the expansion decreased as the lime content increased. Both papers proved the value of lime as a constituent of ordinary glasses.

Professor P. H. Boswell, O.B.E., B.Sc., then addressed the society on "*Impressions of the Glass Industry of the United States gathered on a Recent Visit.*" First of all Professor Boswell dealt with the supplies of raw materials as found in the States, and stated that six sands were in general use, one of them a beautiful sand, from Rockwood, Detroit, was used exclusively for optical glass. The American "sands" are not found as such, but in the form of sandstone (fairly soft). This is blasted, washed by water under pressure, into the bottom of the pit, whence it is dredged up to the top of the pit. It is emptied into concrete bins, and works down through steam pipes until it emerges as dry, clean-running sand. The top layer of steam pipes have a diameter of 3 in., the bottom 1 in., and there is about 1 in. clearance between the pipes. The sand is then loaded into covered wagons, each of which contains 50 tons to 80 tons of sand. The cost of labour in the sand pits is greater than that in this country, the workmen being paid about 1*s.* 6*d.* per hour, and yet the price of sand is less than that of English sand. The price of the washed, dried sand at the pits varied from 5*s.* to 9*s.* per ton, and on the whole was superior to English sand. The cost of transportation also was less than in this country, the highest rate being about 5*s.* per ton. The fact that American sandstone firms can put their sand on the market so cheaply is due to the immense amount quarried per annum. One firm alone quarries nearly 500,000 tons per year. They calculated that the overhead charges for 200,000 tons are not much greater than for 50,000 tons. The quarrymen work about nine hours per day, but contract to keep the bins full, and thus work considerable overtime to make up for loss of output due to bad weather. Professor Boswell afterwards dealt briefly with American supplies of potash and felspar, and then passed on to the question of refractories. He showed a specimen of a glasshouse pot, which had been developed by Dr. Bleininger, and this pot, after the melt had been performed, was perfectly white in colour and very close in texture. In making their pots the Americans were substituting Cornish kaolin by kaolin from Georgia, and were using ball clays from Tennessee and Kentucky in place of those from Devon and Cornwall. Considerable advances have been made in slip casting pots, one firm who were building pots in the English fashion used raw fireclay and grog. Tank blocks were also being made very successfully, and considerable research has been carried out on "Humidity Drying." There was also considerable manufacture of silica bricks in the States, the methods employed being much the same as in the United Kingdom, except that bricks were burnt for a much longer period than in this country. Dr. Boswell then dealt briefly with the various types of glass manufactured in the States, and laid special emphasis upon the number of labour-saving devices in use, which resulted in a huge output.

In the debate which followed, Captain J. R. Clarke, Mr. C. J. Peddle and Mr. F. G. Clarke took part.

Before the meeting the members of the society paid a visit to the works of Messrs. Beatson Clark and Co., Limited, at Rotherham, and the thanks of the society are due to the directors for their kindness on the occasion. The next meeting of the society will be held at Birmingham on March 19, when a paper will be read on the slip casting of pots.

GERMAN AND INTERNATIONAL IRON PRICES.—Much dissatisfaction is expressed in Germany at the price policy of the country, compared with that of other markets. It is urged that whilst a downward tendency manifests itself elsewhere, German manufacturers seem bent upon moving in the opposite direction. In Switzerland prices are giving way owing to French influence, in Holland owing to British, whilst in Germany a further increase of the quotation is being contemplated owing to the desperate conditions of labour, the prices asked for coal, coke and raw materials, the eight-hour day and the rise in wages. A rise in the prices of iron of about 100 marks per ton was decided upon only a few weeks ago; this in most cases raised the prices to more than three times what they were at the beginning of the war. The export prices have also been kept at a very high level, partly even materially higher than inland prices, although there is every reason to anticipate a material all-round fall in prices on foreign markets. The low German exchange of course counteracts somewhat the high quotations, yet keen apprehensions are felt in Germany in this connection.

THE GERMAN ALKALI INDUSTRY DURING THE WAR.

An official report on the position of the German alkali industry during the war points out that, apart from a somewhat speculative rise in the quotations of the shares, this industry has suffered considerably more than have many others. With regard to the sale conditions, the embargo restrictions had materially reduced the sale to the Allied and occupied and neutral European countries and entirely stopped the sale to the United States, but this had been partly counterbalanced by the fact that the home agriculture, as well as that of the neutral countries, at an increasing rate required alkali products owing to the likewise increasing shortage of nitrogen and phosphates. The export to the Allied and neutral countries had been as per the appended table, the figures representing 100 kg. of K_2O:—

—	1913.	1914.	1915.	1916.	1917.
The Netherlands ..	436,700	424,200	291,000	571,200	439,200
Switzerland ..	34,700	42,800	25,400	67,400	47,000
Sweden ..	208,400	259,200	249,900	276,900	158,100
Norway ..	36,800	49,700	39,600	31,200	67,600
Denmark ..	75,300	75,700	78,500	153,100	67,400
Austria-Hungary	283,000	268,400	230,561	326,600	368,000
Belgium ..	152,300	114,806	108,595	104,000	144,300
Russian Poland	—	74,500	12,900	39,700	14,200

The proportion between the foreign and the home sale was as under —:

Foreign	5,055,960	3,684,260	1,191,500	1,570,400	1,305,890
Home ..	6,046,780	5,357,110	5,608,250	7,266,560	8,736,960
Total ..	11,103,694	9,039,883	6,797,764	8,839,700	10,042,850
Value in millions of marks	202½	164½	111½	164	230½

Of the total sale, the distribution was as follows:—

	per cent.	per cent.	per cent.	per cent.	per cent.
Agriculture ..	90·4	91·2	92·0	94·1	95·7
Industry ..	9·6	8·8	8·0	5·9	4·3

The combine movement, which had already commenced before the war, became all the more necessary as time went on, inasmuch as the 191 potash works, in operation on August 1, 1914, had increased to 209 on January 1, 1918. The result of the new system was that 40 out of 50 shafts with temporary, and 59 out of 159 with final, allotments were discontinued. The total number of hands employed on February 1, 1918, amounted to 31,740, including 11,361 prisoners of war and 2,336 women, against a total of 34,316 hands on July 1, 1914. The average wage for the last three months of 1917 was 6·20 marks, against 4·37 marks for 1914, 4·30 marks for 1915 and 4·83 marks for 1916. The state of the different extension works was unfavourable and new installations and preparatory work had, on the whole, been confined to what was absolutely necessary.

CRITICAL POSITION OF THE GERMAN IRON INDUSTRY.—As an example of the critical state arising from diverse causes in which the German iron industry is at present, it may be mentioned that the large Höchst Slöckst Iron and Steel Works in November, 1918, had a loss of 2,000,000 marks, and in December a loss of 3,000,000 marks. These deficits do not contain any writings-off. There will also be a substantial deficit for January. For the sake of comparison it may be added that the Höchst Company for the year ended June 30, 1918, showed works profits amounting to 27,630,819 marks and net profits amounting to 12,566,952 marks.

VACUUM-JACKETED VESSELS OF PORCELAIN.—Vacuum-jacketed vessels of porcelain, made by the Royal Porcelain Manufacture, of Berlin, have been tested at the Reichsanstalt. One vessel was of a capacity of 2·75 litres, and it was compared with a glass vacuum vessel of the same size, both being silvered inside. When charged with liquid air the porcelain vessel lost 28 grammes per kilogramme of liquid by evaporation under given conditions when the glass-jacketed vessel lost 40 grammes, both the vessels being about half full; in this case, therefore, the porcelain vessel was superior to the glass vessel. In similar tests made with water at various temperatures above freezing-point the advantages were reversed, the glass proving the better heat insulator.

VALUABLE COAL DISCOVERIES IN SWEDEN.—The Swedish Government has just granted a concession for coal mining to the large Uddeholm Company. The Swedish Geological Department has proved the existence at Billingen of most valuable coal, having a calorific value of 10,180 calories. Its distillation is expected to yield valuable oils. The coal is also said to contain vanadium. The Skora-Timmerdala railway passes immediately below the coal basin in question, and there are both State and private hydro-electric power stations within a convenient distance. The deposits are located some 4 m. to 5 m. below the top of the mountain, and both the winning and the transport will be exceptionally easy; there will, further, be no trouble from water. The total cost of winning is calculated at 11·50 kronor per ton.

"ENGINEERING" ILLUSTRATED PATENT RECORD.

SELECTED ABSTRACTS OF RECENT PUBLISHED SPECIFICATIONS UNDER THE ACT OF 1907.

The number of views given in the Specification Drawings is stated in each case; where none is mentioned the Specification is not illustrated.

Where inventions are communicated from abroad, the Name, &c., of the Communicators are given in italics.

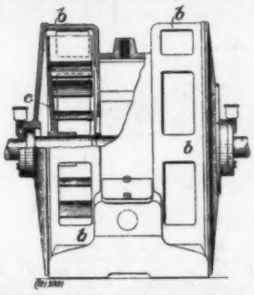
Copies of Specifications may be obtained at the Patent Office, Sales Branch, 25, Southampton Buildings, Chancery-lane, W.C., at the uniform price of 6d.

The date of the advertisement of the acceptance of a Complete Specification is, in each case, given after the abstract, unless the Patent has been sealed, when the word "Sealed" is appended.

Any person may, at any time within two months from the date of the advertisement of the acceptance of a Complete Specification, give notice at the Patent Office of opposition to the grant of a Patent on any grounds mentioned in the Act.

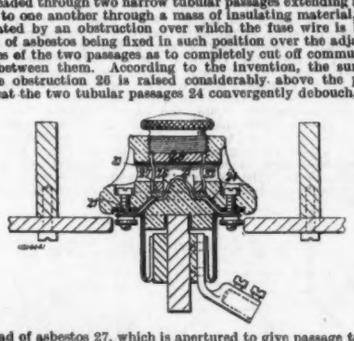
ELECTRICAL APPARATUS.

121,399. W. F. Higgs, Birmingham. Alternating-Current Motors. (2 *Figs.*) February 13, 1918.—According to the invention, there is combined with the motor a centrifugal fan *c*, the discharge edges of the blades of which rotate in a circle of larger diameter than the stator of the motor, the open or inlet side of the fan being presented to one or other end of the stator so that all the air which is caused to enter the fan on the rotation of the same is drawn through and around the stator and rotor windings, a small portion going through the gap between the



stator and the rotor windings, and the remainder through the motor core. The air discharged from the peripheral edges of the blades of the centrifugal fan escapes through openings in the casing of the motor. The centrifugal fan is accommodated in a chamber or compartment *b* at one or other end of the motor casing, the said motor casing being preferably formed with a chamber or compartment at each end so as to admit the fan being arranged at either end of the stator at will. (*Accepted December* 30, 1918.)

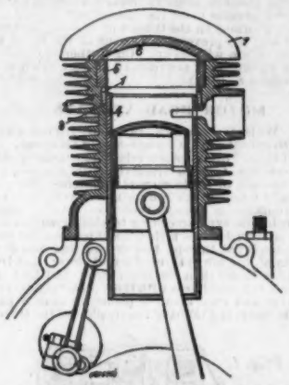
121,664. W. T. Henley's Telegraph Works Company, Limited, London, and E. E. Judge, Gravesend. Electrical Fuse Boxes. (6 *Figs.*) February 5, 1918.—This invention relates to electrical fuse carriers of the kind wherein the fuse wire is threaded through two narrow tubular passages extending at an angle to one another through a mass of insulating material, and separated by an obstruction over which the fuse wire is bent, a pad of asbestos being fixed in such position over the adjacent orifices of the two passages as to completely cut off communication between them. According to the invention, the summit of the obstruction 26 is raised considerably above the plane whereat the two tubular passages 24 convergently debouch, and



the pad of asbestos 27, which is apertured to give passage to the projecting portion of the obstruction, does not overlie that part of the fuse wire 21 which is bent over the obstruction, so that the gases evolved on the fusion of this part of the wire in the event of the fuse blowing are free to escape through ventilation holes 31, 32 provided in the wall of the fuse carrier, without gaining access to the contact terminals. The asbestos pad 27 may be retained in position by a disc or cap 28 superposed on the pad and apertured to give passage to the obstruction 26 and the contiguous portion of the fuse wire; this disc or cap being secured by means of a member removably attached to the body of the fuse carrier (as for example, by being screwed upon or into the latter). (*Accepted January* 8, 1919.)

GAS ENGINES, PRODUCERS, AND HOLDERS, &c.

121,673. T. A. N. Leadbetter, Hale, A. L. Knox-Gilchrist, Lytham, and W. H. Tate, Ashton-on-Mersey. Internal-Combustion Engines. (2 *Figs.*) February 26, 1918.—This invention relates to internal-combustion engines of that type in which the passage of the gases to and from the working cylinder is controlled by a reciprocating sleeve valve. The packing ring 1 is housed in the wall 2 of the cylinder. The usual depending head of the cylinder is dispensed with, and a groove 3 formed in the cylinder wall, into which is fitted the packing ring 1, which tends to contract inwardly, so that it presses against the outer curved face of the sleeve valve 4. This packing ring 1 is kept in its groove by means of an upper retaining ring 5, which sits in another radially deeper groove on top of the packing-ring groove, and is itself held in place by the detachable cap head 6 of the cylinder. This cap head 6 does not depend into the cylinder, and consequently may be quite effectively cooled by means of the fins 7. A slight end clearance is provided between the retaining ring 5 and the packing ring 1 in order to permit of free inward pressure of the packing ring against the sleeve valve 4. In such a construction, an ordinary domed type of cap head for the cylinder may be provided as shown,



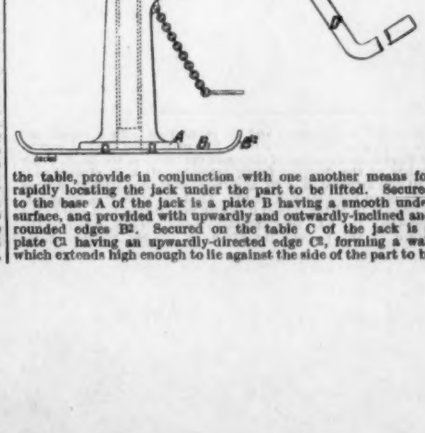
to close up, and the gastight sealing action of the ring actually improves, therefore, as wear takes place. The disposition of the packing ring in the cylinder wall with reference to the extreme end of the sleeve valve is such that the latter in its lowest position is still in contact with the packing ring and does not over-run it. The invention is applicable to any type of sleeve-valve engine, whether comprising a single cylinder or a duplex engine having twin cylinders. (*Accepted January* 8, 1919.)

121,536. N. Rees, Bretfell Lane, near Stourbridge. Regenerative Bricks or Blocks. (2 *Figs.*) January 19, 1918.—This invention relates to honeycomb work of regenerative hot-air stoves which is built up of bricks or blocks which have openings therethrough for the passage of gas and air alternately, and which also form between them when built up passage-ways for the passage of gas and air alternately. According to this invention, the surfaces of the bricks or blocks which, when the bricks or blocks have been built up, receive and radiate the heat are formed as corrugations, which run endwise of the passages through which the gases and air pass alternately. Each brick A is formed with a passage-way *a* therethrough, and with a number of radial projections *a*¹ which butt against corresponding projections of the surrounding bricks, whereby a number of passage-

ways *b* are formed between the bricks in addition to the passage-ways *a* which pass through them, the passageways *b* being conveniently each of the same size and shape as the passage-ways *a*; but, according to this invention, the openings which form the passage-ways *a* are corrugated, as shown, and the bricks are so shaped that the openings which form the passage-ways *b* are similarly corrugated. Preferably, the corrugations are formed of reverse curves, which run tangentially into one another, and preferably also the hollows of the interior corrugations lie in the directions of the radial projections, whereby the bricks may be made lighter for their strength than would be the case if the hollows were differently situated in respect of the projections, and the hollows of the exterior corrugations form the sides of the projections. (*Accepted December* 31, 1918.)

LIFTING AND HAULING APPLIANCES.

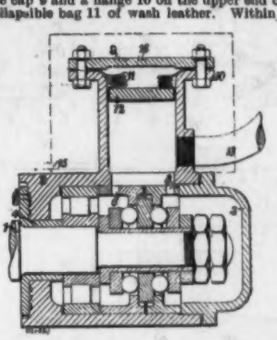
121,671. R. W. Maudslay, Coventry, and The Standard Motor Company, Limited, Coventry. Lifting Jacks. (1 *Fig.*) February 18, 1918.—According to this invention, a lifting jack (for example, a screw jack) comprises in combination therewith a base with a smooth underside and upwardly-turned edges, and a table provided at one side with an upwardly-directed portion. The formation of the base, and also the projection on



the table, provide in conjunction with one another means for rapidly locating the jack under the part to be lifted. Secured to the base A of the jack is a plate B having a smooth under surface, and provided with upwardly and outwardly-inclined and rounded edges B². Secured on the table C of the jack is a plate C¹ having an upwardly-directed edge C², forming a wall which extends high enough to lie against the side of the part to be lifted when the table is in contact with its under surface. The handle D of the jack is provided with a cranked end D¹. The handle is attached to the jack by the provision upon it of a squared end, which enters a correspondingly-shaped socket, and is there held in known manner by a pin secured against loss by a chain attached to the body of the jack. It will be seen that in usual manner the jack can be pushed under the car to any desired position by means of the handle D. The inclined edges B² enable the base B to ride easily over rough ground without upsetting the jack, and the smooth under surface adds to the ease of movement of the jack into position. The jack is slid along until the wall C² upon the table C comes into contact with the side of the part to be lifted, for example, the axle of the car, and when this occurs the jack is correctly located for lifting. By means of the cranked handle D¹ the lifting mechanism can be rotated rapidly, and without constantly removing the hands to take a fresh grip, as is necessary when a tee-ended handle is used. It will be seen that the baseplate B, and the table plate C¹, with its wall C², can be made either integral with the jack or as separate parts as shown, so as to be readily applicable to jacks of usual construction. (*Accepted January* 8, 1919.)

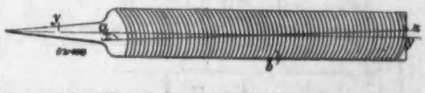
MACHINE AND OTHER TOOLS, SHAFTING, &c.

121,491. J. S. Highfield, Kensington, London. Bearings. (1 *Fig.*) January 18, 1917.—This invention relates to shaft bearings intended to be run under water. According to this invention, the shaft bearing is so constructed that access of the water to the interior of the bearing is prevented by providing a reservoir connected to the interior of the bearing and containing lubricant which is subjected to a pressure produced by the head of water above the bearing in addition to a pressure which is not so produced. The bearing shown is an end bearing into which the shaft 1 projects and comprises a housing 2 closed at one end by a cap 3. Fixed on the shaft 1 is a collar 4, provided with annular projections 5, which intermesh with projections 6 on the housing 2. Integral with the housing is a cylinder reservoir, which is open to the interior of the bearing through openings 8. The reservoir may be closed by a cap 9. Clamped between the cap 9 and a flange 10 on the upper end of the reservoir is a collapsible bag 11 of wash leather. Within the bag is



placed a weight 12. The reservoir beneath the bag is filled with lubricant through the pipe 13. The weight 12 serves to subject the lubricant to a steady pressure so that the lubricant tends to flow outwards thereby preventing the liquid in which the bearing is immersed from entering the interior of the bearing. The intermeshing projections 5 and 6 also provide a long passage and tend to prevent the liquid creeping into the bearing. The reservoir is enclosed in a chamber indicated by chain lines, which chamber is provided with an opening at 15. The liquid entering the chamber, compresses the air above it, and an opening 16 being provided in the cap 9, the pressure generated is transmitted to the bag 11, and therefore to the lubricant. The effect of the head of water in tending to force the water into the bearing through the passage between the collar 4 and the housing 2 is therefore neutralised, and the pressure tending to force the lubricant out of the bearing is merely that due to the weight 12. (*Accepted December* 31, 1918.)

121,498. C. O. Schneider, Wimbledon, London, and J. J. Pritty, London. Files. (4 *Figs.*) October 18, 1917.—This invention relates to files in which the teeth are of arcuate form or are arranged upon arcs of circles, extending across the face of the file. According to this invention, instead of the centres of the arcs being located upon the centre line of the file they are disposed upon a line inclined with respect to said centre line. The line of the centres may be such that it bisects the centre line in the middle of the length of the file, or at any other point, or it may be disposed upon one side of said centre



line, and be either wholly contained within the width of the file or be partly or wholly outside thereof. *a* indicates the body of the file and *b* the teeth, which are of arcuate outline, extending uninterruptedly across the face of the file. The teeth are all arcs of circles or equal radii, and the line of the centres of said teeth are disposed upon the line *x x*, which, as will be seen, is disposed at an angle relatively to the centre line *y y* of the file. By this means the angle at which the teeth meet the work is constantly changing through the stroke of the file. (*Accepted December* 31, 1918.

121,685. R. Sutcliffe, Horbury. Shaft Couplings. (2 *Figs.*) March 27, 1918.—The coupling is of the known type in which the shafts are connected by a sleeve in which are provided two bolts passing through the shafts mutually at right angles to each other and to the axes of the respective shafts, each shaft being adapted to rock or swivel about the bolt passing through the common member. According to the invention, the bolts D¹, D² pass through sockets or cuffs B¹, B² secured to the shafts A¹ A², and adapted to rock in contact with the internal surface of the outer sleeve or muff C; for this purpose the longitudinal section of each socket is slightly convex. The arrangement ensures that the wear due to the working of the bolts in the holes provided in the shafts is transferred to the sockets, which are easily renewable, and the life of the shafts is consequently prolonged. Also the rocking contact of the sockets with the internal surface of the sleeve C prevents the play of the shaft in any direction at right angles to its axis, while allowing the required inclination between the axes of the shafts. The internal diameter of this muff may conform with the external maximum diameter of the cuffs throughout its length, or it may be part *y* cupped or convave to conform with the contours of

the cuffs. Each cuff is tightly keyed on its respective shaft, the keyways being in planes preferably at right angles to each other and to the shafts, the cuffs and muff are coupled by pins or bolts passing through the shafts at right angles to the axis

Fig. 1.

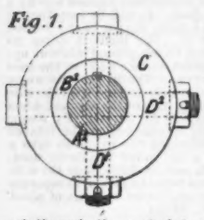
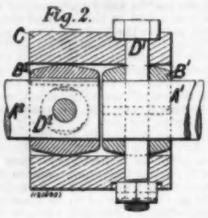


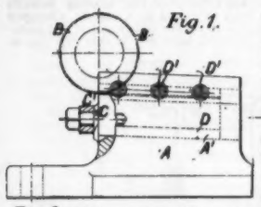
Fig. 2.



and through the central transverse planes of the cuffs, and substantially at right angles to the keyways in the cuffs. (*Accepted January* 8, 1919.)

121,696. William Beardmore and Co., Limited, Glasgow, and T. Broadbent, Glasgow. Holder for Form-Tools. (3 *Figs.*) January 8, 1918.—The invention has for its object a holder for form-tools—that is to say, tools, the profile of the cutting edge of which is counterpart to the profile of the work—in lathes such that the tool may be in the form of a bar or a series of bars assembled together of the required contour, with the cutting end at an angle to the base—thus, the tool may be sharpened simply by grinding the end and "backing-off" or equivalent processes for providing tool clearance be dispensed with. The base A is secured to the cross-slide of a lathe, and the groove A^1 is not only at a greater angle than a tangent to the

Fig. 1.



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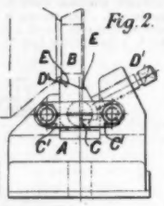
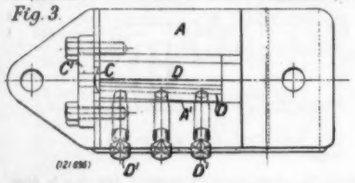


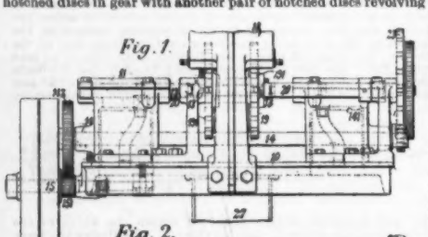
Fig. 3.



work B, but is also inclined in the plane of rotation of the work. At the inner end of the groove a locating stop C is provided in a cross-piece C^1 secured to the base by studs. The form-tool D, in two parts, is located against the back and the bottom of the groove by set pins D^1 entered at an angle through one of the side walls of the groove, and its cutting faces E, E^1 are contoured counterpartly to the profile of the work B. It will be seen that the base is so adjusted in height that the tool performs its cut while passing beneath the lathe centre—that is to say, at a point cut by a line passing through that centre and at an angle of the movement of the slide carrying the base. (*Accepted January* 8, 1919.)

121,705. Greenwood and Batley, Limited, Leeds, and T. Atkinson, Upper Armley, Leeds. Tube-Bulging Machines. (4 *Figs.*) July 25 1918.—This invention relates to improvements in machines for bulging the ends of tubes. According to this invention, the tubes are brought opposite the bulging tools by means of a pair of intermittently rotating notched discs in gear with another pair of notched discs revolving

Fig. 1.



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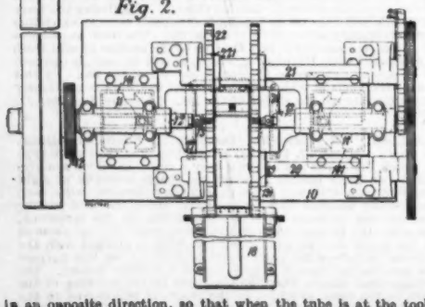
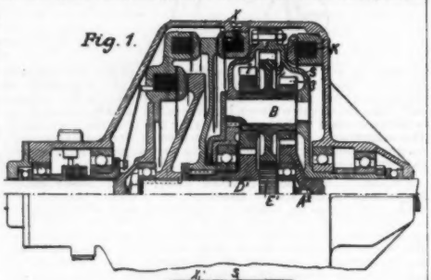


in an opposite direction, so that when the tube is at the tool station, the two pairs of discs completely encircle it, maintaining it in its circular form while the tools expand its ends, and act as strippers when the tools are withdrawn after the bulging operations. Upon a table 10 are mounted two headstocks 11, each supporting a spindle 12 having at its end a bulging tool 13. The spindles 12 are actuated by cams 141 mounted on a shaft 14, driven through a toothed wheel 142 gearing with a pinion 151 running free on a shaft 15, upon which turn loose and fast pulleys 17 and 16, the latter being fast with the pinion 151. The tubes to be operated upon pass down a shoot 18 into the notches 191 in two discs 19 keyed to a shaft 20, and on a shaft 21 are two discs 22 having notches 221, the shafts 20 and 21 being geared together. On the shaft 21 is a segment wheel 23 driven intermittently. The discs 19 and 22 are intermittently turned until the notches 191 and 221 co-act and hold the tubes, and while they are so held the spindles 12 move towards them and the bulging tools 13 on the spindles enter the ends of and expand the tubes, shoulders being formed on the tubes which, being in contact with the discs 19 and 22, prevent movement of the tubes when the bulging tools 13 are withdrawn. On further movement of the discs 19 and 22 the tubes are released and fall down a shoot 27. (*Accepted January* 8, 1919.)

MOTOR ROAD VEHICLES.

121,616. Wolseley Motors, Limited, Birmingham, and E. Reeve, Birmingham. Change-Speed Gearing. (2 *Figs.*) October 25, 1917.—This invention relates to change-speed gearing of the spur epicyclic type, in which the change of speed ratios is effected by the aid of electromagnetic clutches, the gear being more especially intended for use on motor vehicles. One form of an electromagnetic change-speed and reverse gear of the spur-wheel epicyclic type according to this invention is characterised by a construction such that the three co-axial sun wheels A2, D1, E^1 employed therein, two driving and one driven, are not only co-axial, but are of three different sizes; that the driven sun wheel A2 is larger than the other two; and that the three planet wheels 3, 1, 2, which gear with them (*a*) are rigidly connected to one another and turn about a planetary axis B parallel to the axis of the suns, and (*b*) have the smallest of the three planets

Fig. 1.



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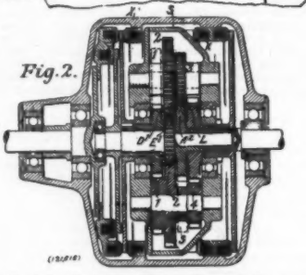
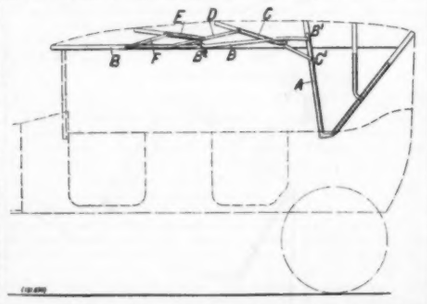


geared to the largest of the three suns, whereby a reverse is obtainable as well as three forward speeds, and that two of the forward speeds are obtained by holding stationary the support S of the planetary shaft B. An alternative construction of electromagnetic change speed and reverse gear of the spur-wheel epicyclic type according to this invention differs from that which is above referred to by the addition of an extra planet pinion 4 fixed to the others, and of a brake-controlled fourth sun wheel L with which it gears, the fourth sun wheel being loose and turning on bearings that are co-axial with the driving shaft, and being also combined with a stationary electromagnetic brake K appropriated to it, whereby it can be locked to and released from the stationary casing X of the mechanism to enable additional speeds to be obtained, forward or reverse as desired. (*Accepted January* 8, 1919.)

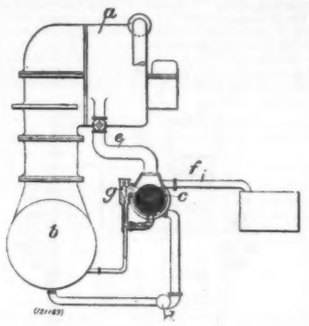
121,670. R. W. Maudsley, Foleshill, Coventry, and The Standard Motor Company, Limited, Foleshill, Coventry. Motor Road Vehicles. (1 *Fig.*) February 18, 1918.—This invention relates to hoods for use on motor vehicles of the kind in which an extension is provided, which projects over the front seats in the case of a four-seated car. According to this invention, in a hood of the type described there is provided a supplementary hood-stick, characterised in that it has only two connections on each side of it with the remainder of the hood frame, namely, its pivotal connection to the side link which connects the first



and second hood sticks, and its connection with a supporting link carried by the front stick. The main hood stick A carries the known construction of the front extension of the hood, which consists of the first, or front, extension stick B, pivoted to it at B^1 and articulated at B^2, and the second hood stick C, pivoted to the main hood stick A at C^1. The hood stick C is supported by links D on either side of it, which are pivoted to it and to the hood stick B. The supplementary hood stick E, which is the feature of the present invention, is pivoted to the above-mentioned side links D, and is itself provided with supporting links F, which are pivoted to it and to the hood stick B at a point in advance of the pivots of the links D. The supplementary hood stick E and its supporting links F are so proportioned and situated on the front extension, and their pivots are so located that when the hood is folded in known manner the hood stick E lies closely between the first and second hood sticks B and C. It will be seen that by the provision of the above-described supplementary hood stick the hood fabric is supported between the front extremity of the hood stick B and the hood stick C, thus avoiding the excessive sag liable to occur there. (*Accepted January* 8, 1919.)

STEAM ENGINES, BOILERS, EVAPORATORS, &c.

121,169. The British Thomson-Houston Company, Limited, London, and F. Samuelson, Rugby. Feed-Water Heaters and Steam Condensers. (2 *Figs.*) December 1, 1917.—This invention relates to power plants in which part of the exhaust steam from the engine or turbine is used to heat the feed-water supply to the steam generator. The invention consists in dividing the feed-water heater surface into two elements, the upper part of the tubes condensing the steam, and the lower part cooling the condensate, which covers the latter by automatically maintaining the condensate in the feed-water heater at a suitable level; and causing the condensate from the main condenser on its way to the hot well tank to pass first through the lower cooling tubes of the feed-water heater and then through the upper tubes in contact with the heating steam.



a represents the turbine and *b* the main condenser from which the condensate is pumped into the feed-water heater *c* by means of a centrifugal pump *d*. The feed-water heater is supplied with steam from a suitable stage in the turbine *a* through the pipe *e*. The heated feed water passes to the boiler or feed tank through pipe *f*. The pump *d* withdraws water from the main condenser *b* and discharges it through the cooling tubes of the heater *c*, entering at the lowest and leaving from the uppermost. The water in the lower portion of the heater is thereby cooled, and the heating steam in the upper part is condensed while the feed water is heated. In order to regulate the amount of water in the heater so that the desired amount of tubing may be unsubmerged and acted upon by the steam withdrawn from the turbine, a float *g* operating a valve is provided. When the level of the water in the heater reaches a predetermined point, this float raise the valve from its seat and allows the surplus water to drain into the condenser. (*Accepted December* 18, 1918.)

121,313. R. S. Portham, London. Condensers and Coolers. (2 *Figs.*) November 13, 1917.—This invention relates to condensers or coolers of the evaporative type. A condenser or cooler, according to the present invention, comprises a stationary heat-exchanging device having a distributing chamber, a collecting chamber and radially-disposed tubes connecting said chambers, and rotating means mounted above said tubes for drenching them with evaporative liquid, whereby each tube or group of tubes is, in succession, intimately drenched with the evaporative liquid, the period between successive drenchings being such that the film of liquid on the surfaces of the tubes is allowed to evaporate before the next drenching occurs. A heat exchanging device comprises tubes 3 disposed between two concentric chambers 4 and 5, the outer one 5 being of annular form. The axes of the chambers are vertical, the tubes 3 being substantially horizontal and preferably straight

Fig. 1.

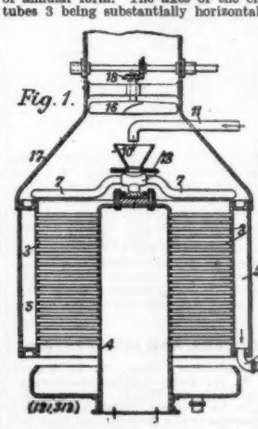
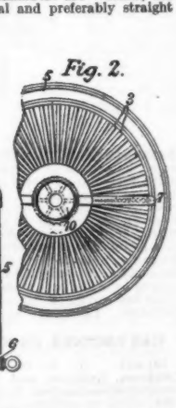


Fig. 2.



and radially disposed. Exhaust steam from the prime mover enters the chamber 4 at the lower end and passes through the tubes 3 to the chamber 5, which is connected by the pipe 6 to a pump and/or ejector. Mounted above the heat-exchanging device so as to rotate is a distributing device comprising two radially disposed arms 7 having a plurality of apertures. The radial arms are connected to a funnel 10, to which evaporative liquid is supplied by the pipe 11. The distributor is rotated by the chain wheel 13. The tubes 3 are thoroughly wetted by evaporative liquid flowing from the arms 7. Air, either pre-heated or otherwise, is led preferably upwardly and between the tubes 3, and may be caused to flow by means of the fan 16 arranged in the uptake 17 and driven by gearing 18. (*Accepted December* 30, 1918.)